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SUBTERRANEAN FAUNA OF TWELVE ISTRIAN CAVES

Slavko POLAK
Zavod Znanje, OE Notranjska Museum Postojna, SI-6230 Postojna, Kolodvorska c. 3, Slovenia
E-mail: slavko.polak@notranjski-muzej.si

Jana BEDEK & Roman OZIMEC
Croatian Biospeleological Society (CBSS), HR-10 000 Zagreb, Demetrova 1, Croatia

Valerija ZAKŠEK
University of Ljubljana, Biotechnical Faculty, Department of Biology, SI-1000 Ljubljana, Večna Pot 111, Slovenia

ABSTRACT

The subterranean fauna of twelve Istrian caves, six in Slovenia and six in Croatia, is presented in this paper. Caves in the carbonate region of White Istria (Čičarija) host the richest troglobiotic fauna in comparison to caves in the carbonate littoral region of Red Istria and the intermediate flysh region of Grey Istria. Caves in the contact zone of limestone and flysch situated in Grey Istria are inhabited by a surprisingly high number of troglobiotic taxa as well. Some subterranean taxa were found relatively far from their known distributional areas. In addition, several new taxa have been discovered for science. We briefly describe the general ecological conditions within the caves and estimate potential threats to their faunas. Istrian caves are inhabited by numerous endemic troglobiotic species, in this respect ranking this region close to the most diverse Dinaric region.

Key words: subterranean fauna, troglobionts, cave conservation, Istria

FAUNA SOTTERRANEA DI DODICI GROTTE ISTRIANE

SINTESI

L'articolo presenta la fauna sotterranea di dodici grotte istriane, sei delle quali presenti in Slovenia e sei in Croazia. Le grotte della regione carbonatica dell'Istria Bianca (Ciceria) ospitano la fauna di troglobi più ricca in confronto alle grotte della regione carbonatica costiera dell'Istria Rossa e della regione flyschoide intermedia dell'Istria Grigia. Peraltro, anche nelle grotte della zona di confine fra calcare e flysch, situate nell'Istria Grigia, è stato trovato un numero sorprendentemente alto di taxa di troglobi. Alcuni taxa sotterranei sono stati trovati relativamente lontano dalle loro aree di distribuzione conosciute. Nell'articolo vengono inoltre segnalati alcuni taxa nuovi per la scienza. Gli autori descrivono brevemente le condizioni ecologiche generali all'interno delle grotte, e valutano i fattori che potrebbero nuocere alla fauna locale. Le grotte istriane ospitano numerose specie endemiche di troglobi, al pari della ben diversa regione dinarica.

Parole chiave: fauna sotterranea, troglobi, tutela delle grotte, Istria

INTRODUCTION

The Istrian Peninsula consists of three main geomorphological units extending from (in order from northeast to southwest) the inner, partly mountainous limestone region known as White Istria; the external, low limestone plateau with typical red soils called *Red Istria*; and a hydrological barrier flysch zone in between known as Grey Istria (Krebs, 1907). Up to now, over 2000 caves have been registered in Istria, mostly in limestone. There are also caves which have developed in the contact area between flysch and limestone. The Istrian Karst is relatively well isolated from the main Dinaric Karst, and for this reason caves in Istria are very interesting for biological research. Although biospeleological exploration in Istria began early in the second half of the 19th century, the subterranean fauna of the area is not well known and has not been systematically explored and evaluated. Unfortunately, caves, springs and their fauna are under strong pressure from human activity (Sket, 1999; Culver & Pipan, 2009; Ozimec *et al.,* 2009; Polak & Pipan, 2011).

Geopolitically, the Istrian peninsula is divided among Croatia, Slovenia and Italy, a fact which necessitates international cooperation. Within the Karst Underground Protection project (KUP), biospeleological surveys, identification of potential threats to the subterranean environment and accompanying popularization activities have been carried out (Ozimec *et al.,* 2010, 2011). This project was financed by the OP IPA Slovenia - Croatia 2007–2013 program and led by the Istrian Region, with Natura Histrica as the Croatian partner and the Karst Research Institute ZRC SAZU from Postojna as the Slovenian partner. The aim of the speleobiological research within the framework of the KUP was to evaluate species richness and the ecological conditions of the subterranean habitats in Istria through a systematic survey of selected caves. In this paper we present an overview of the faunistic findings within twelve selected caves from Slovenian and Croatian Istria.

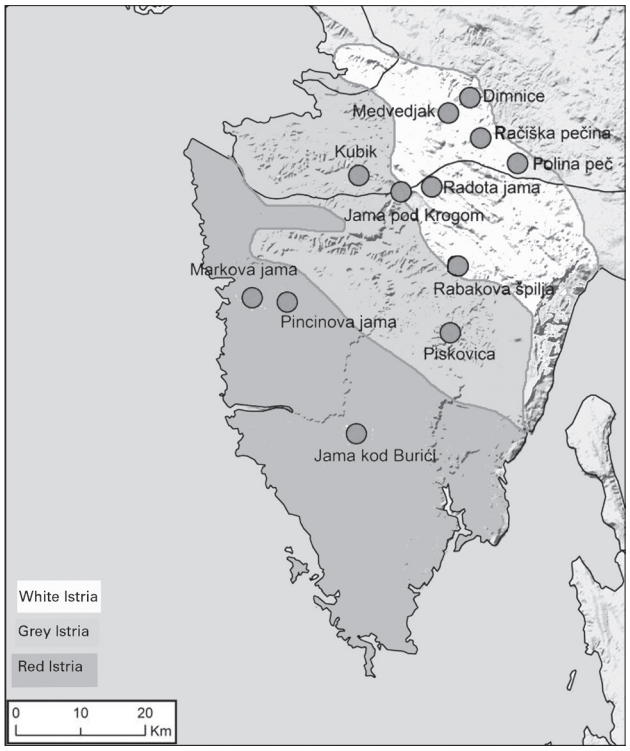

Fig. 1: Map of Istria showing locations of the12 caves investigated.
Sl. 1: Zemljevid Istre z lokacijami 12 raziskovanih jam.

Caves under study

In total, twelve caves were selected for investigation, six in Slovenia and six in Croatia (Fig. 1). Six of them were in Čičarija (White Istria), three in the contact zone of limestone and flysch (Grey Istria) and three caves were in the littoral region of Red Istria.

Some of the selected caves provide terrestrial and aquatic habitats (springs, subterranean rivers and lakes), whereas others feature only terrestrial habitats. The caves differ in terms of accessibility and use: some are accessed through an entrance shaft and are more difficult of access to people, while others are horizontal and regularly visited. Two of these caves have been used for tourism or by the military. In the following, we briefly present the caves being investigated. Cadastre Number (Cad. No.) refers to the corresponding Slovene cave cadastre. Number (Pećina br.) corresponds to the number of Istrian caves (Malez, 1960) and number No. VG (Grotte della Venezia Giulia) refers to the old Italian cave cadastre (Boegan, 1930).

1. Polina Peč (Cad. No. 938), Poljane, Obrov, Matarsko podolje, Čičarija, Slovenia

Synonymy: Caverna di Pogliane presso Castelnuovo, Polina pecina, No. 1105 VG (Müller, 1930).

With its entrance at the bottom of a small doline, this cave is easily accessible. It is 365 m long and 40 m deep, consisting of a large descending entrance hall, a narrow passage and a huge inner chamber. The temperature of the entrance hall is strongly influenced by cold air, especially in winter when ice is regularly deposited to the very bottom.

2. Račiška Pečina (Cad. No. 942), Račice, Starod, Matarsko podolje, Čičarija, Slovenia

Synonymy: Pečina pri Račicah, Grotta di Racizze, No. 613 VG, presso Castelnuovo (Müller, 1930).

The cave is horizontal and 304 m long by 29 m deep. Between World War I and II and until the 1980s, the cave was used as a fuel storage place for military purposes. For this reason, some parts of the cave have been devastated; the floor has been artificially levelled and the cave is partly polluted with oil. In the inner part,

bones and traces of a cave bear (*Ursus spelaeus*) have been discovered (Mihevc, 2003); due to these discoveries, the cave has been closed for conservation purposes since 2007.

3. Dimnice (Cad. No.735), Markovščina, Materija, Matarsko podolje, Čičarija, Slovenia

Synonymy: Grotte de Markovsina ou grotte d'Innice, Höhle bei Markovscina (Müller, 1905), Grotta Dimnice nei dintorni di Markovscina (Müller, 1906), Rauchgrotte bei Markovščina (Perko, 1909), Grotte Dimnice ou grotte qui fume, à Markovsina (Jeannel, 1911), Grotte di Marcossina detta Grotta del Fume, No. 626 VG, Grotta Dimnizze presso Slivje (Müller, 1928), Dimnica jama (Rauchgrotte) bei Slivia (Stammer, 1932).

The total length of the passages is 6020 m; the cave is 134 m deep. The Dimnice cave is the only tourist cave included in our study. Down the 39 m deep entrance pit, the cave extends into horizontal passages and chambers of impressive dimensions, some of them being 20 m wide and high. Relatively small water current flows through Dimnice.

4. Medvedjak (Cad. No. 881), Markovščina, Materija, Matarsko podolje, Čičarija, Slovenia

Synonymy: Medvedova jama, Grotta dell' Orso presso Markovsina (Perko, 1909), Medvedova jama bei Markovšina (Müller, 1913), Grotta dell'orso (medvedova jama) dist. Marcousina (Müller, 1928), Grotta ai piedi del Monte Medvediak, No. 70 VG, Grotta dell 'orso presso Marcossina, tra Cosinae Castelnuovo (Müller, 1930).

The total length of the cave is 1091 m with a depth of 129 m. The entrance section of the cave is a 45 m deep bell-shaped pit with a huge hall beneath. From this point, more or less horizontal galleries extend in different directions. In the upper parts there are many speleothemes, whereas the lower galleries are mostly muddy.

Jama Pod Krogom (Cad. No. 4524) – Špilja pod Krugom (Bedek *et al.,* 2006)., Mlini, Sočerga, Čičarija, Slovenia–Croatia

5. The Jama Pod Krogom spring cave is situated in the contact zone where the Paleocene limestone thrusts over the Eocene flysch. The cave is 570 m long and ascends for 25 m. The entrance opens on a vertical rock cliff, right on the Slovene - Croatian border. During rainy periods, the whole cave is flooded and water flows out at the entrance. During dry periods the water is caught in the cave lakes and siphons several meters above the level of the permanent spring in the village of Mlini (Habič *et al.,* 1982).

6. Kubik (Cad. No. 4524), Brezovica pri Gradinu, Koprska brda, Slovenia

Synonymy: Kobiak.

The Kubik cave is a 292 m long horizontal cave of small dimensions. The entrance opens into a small pit. In its farthest and lowest section where a small stream and water pools occur, the cave is 10 m below the surface. The cave lies in on the contact between flysch sandstones and nummulite, turbidite limestone originated by small stream erosion.

Rabakova Špilja, Roč, Ročko polje, White Istria, Croatia

Synonymy: Kerbauc pećina, Ročka Špilja, Grotta di Rabaco dei Bencici, No. 1193 VG, Pećina br. 4 (Malez, 1960).

7. Rabakova Špilja is 143 m long and 22 m deep (Malez, 1960). The cave was formed by the erosion of nummulite, turbidite limestones caused by periodic water flow. It is a complex cave system consisting of two morphologically different channels with periodic water flow in the lowest part.

8. Radota Jama, Radota brdo, Rakitovec, Brest, Buzet, White Istria, Croatia

Synonymy: Grotta di Garnchino (Radetik), No. 298 VG, Pećina br. 42 (Malez, 1960).

8. Radota Jama is located on the southwestern side of the Radota hill in Čičarija. It represents a simple cave system, 268 m long and 170 m deep (Malez, 1960). In the eastern part of the main cave chamber, a steep, partly vertical 150 m long channel starts, with an intermittent water pool on the bottom. The channel is completely covered with sinter.

9. Piskovica, Jaklići, Gologorica, Pazin, Grey Istria, Croatia

Piskovica is mostly a horizontal, 1036 m long passage, representing a simple, hydrologically active cave system. Two dozen meters before the end of the cave at its deepest point of 38 m, there are collapsed blocks with a water current flowing through. Piskovica cave was formed by water flow erosion of flysch sediments located between limestone layers. The cave has a unique and attractive morphology resembling a straight rectangular tunnel (Jekić & Zlokica, 1988).

Markova Jama, Štancija Špin, Tar, Poreč, Red Istria, Croatia

10. Markova Jama is a complex 291 m long and 82 m deep pit system with two entrances, one of them closed at the moment. The cave was discovered in 1975 (Legović, 1985). The deepest point at 82 m is 18 m below sea level; at this point a 3 m deep lake is located.

11. Jama Kod Burići, Kanfanar, Red Istria, Croatia

Jama Kod Burići is a complex, 100 m long and 127 m deep pit, with a narrow (0.5 x 0.7 m) entrance. A long inner chamber extends into several muddy pits. Jama Kod Buriči is hydrologically active during heavy rains (Legović, 1999).

12. Pincinova Jama, Tar, Poreč, Red Istria, Croatia.

The entrance of the cave Pincinova Jama is located at the bottom of a small doline in the vicinity of the village of Monfaber near Poreč. The cave is 100 m long, with the deepest point at 85 m (Legović, 1985). It is a simple pit with an underground water pool. The lake is, on average, 22 m deep. Since its discovery in 1976, many speleological research studies have been carried out within the cave.

MATERIALS AND METHODS

At the beginning of our research, published information on the caves with respect to their geomorphology, physical properties and faunas was compiled and studied. The speleological data, including the cave maps of Slovene caves were obtained from the Slovene Cave Cadastre (IZRK ZRC SAZU and the Slovene Caving Association). The maps and data for the Croatian caves were obtained from published reports (Malez, 1960; Legović, 1985, 1999; Jekić & Zlokolica, 1988). Older cave catalogues (Bertarelli & Boegan, 1926; Garibaldi, 1926; Boegan, 1930) were also studied. The published faunistic records were taken from the cave fauna catalogues (Hamann, 1896; Wolf, 19341938) and from numerous papers and revisions of particular animal taxa.

Field work in the selected caves was carried out during between two to four visits (at least two per cave) in different seasons. Measurements of environmental parameters are irrelevant for this study and are not presented here. The fauna was studied by systematic visual inspection of the cave floor, walls, ceiling and water micro-habitats. Sampling with baited pit-fall traps was not applied, except for one occasion in the Medvedjak cave to collect beetle specimens for photographic documentation and molecular studies. Most of the recorded species were photographed. Selected specimens were collected and preserved for further investigation. The biological samples from Slovenia are deposited in the Zoological Collection of the Department of Biology (Biotechnical Faculty, University of Ljubljana) and in the Notranjska Museum Postojna (Postojna). The material from Croatia is deposited in the Collection of the Croatian Biospeleological Society (HBSD). The collected fauna were mostly identified by the authors although some species were delivered to other experts.

We used classical classifications of subterranean environments and their associated fauna (*e.g.*, Schiner, 1854; Camacho, 1992; Sket, 2008; Culver & Pipan, 2009, Novak *et al.,* 2012). Troglobionts (stygobionts in the case of aquatic taxa) complete their life cycle in a completely dark, humid/water and thermally stable hypogean environment. Most of these clearly show troglomorphism. Troglophiles alternate between epigean and hypogean habitats or live permanently in subterranean habitats, and show some moderate adaptations to subterranean conditions, such a reduced eyes and adaptations to compensate for the lack of visual orientation. Some among these do not complete their life cycle underground, while others do. Trogloxenes are taxa which enter caves for shelter or feeding opportunities, but which exhibit no morphological adaptation to the hypogean environment and do not complete their life cycle there. Some edaphobionts living in soil are also common in the entrance sections of caves. Most of our field work focused on the troglobionts. Troglophiles and particularly trogloxenes were not sampled systematically. Small aquatic invertebrates (Turbellaria, Oligochaeta etc.), microscopic crustacean fauna (Copepoda), micro-organisms and fungi were not sampled and are not considered in this study. Owing to the lack of experts in some taxa and the absence of adult stages, some taxa have not been determined to the species level.

The lists of the subterranean faunas of the three regions - White, Grey and Red Istria - were tested for differences in the presence or absence of species using the Cochan Q test (Sokal & Rohlf, 1995), where 1 indicates the presence and 0 the absence of a species.

RESULTS

Our findings on the subterranean faunas, as well as the faunistic records from literature about these studied caves are summarised in Table 1.

1. Polina Peč

The fauna was investigated on 19.10.2010, 4.3.2011 and 22.6.2011. The cave is the type locality of the trechine beetle *Anophthalmus schmidti istriensis* (Müller, 1909) and the troglobiotic pselaphine beetle *Mahaerites novissimus* (Nonveiller & Pavićević, 2001). Apart from the original descriptions, the only published faunistic data from Polina Peč were reported by Polak (1997). During our investigations the presence of the trechine *Typhlotrechus bilimeki istrus* (Fig. 5) and the sphodrine *Laemostenus cavicola cavicola* were stated as common; however, surprisingly, no leptodirine *Leptodirus hochenwartii reticulatus* was found. Some forgotten pit-fall traps left by collectors were found. So far, 15 troglobionts have been recorded from this cave (Tabs. 1, 2). Among other invertebrates, our discovery of the cave centipede *Eupolybothrus obrovensis* is significant, since only a couple of Slovenian localities have so far been identified (Matic & Darabantu, 1968). In this cave the troglomorphic diplurian *Plusiocampa* cf. *nivea* (Fig. 7) is common. A small number of the woodlice *Titanethes dahli* and *Alpioniscus* cf. *strasseri* were also found.

2. Račiška Pečina

Before the military use of the cave, some biologists (J. Stussiner, J. Müller, K. Strasser) visited the cave and found the trechine beetle *Typhlotrechus bilimeki istrus* and the oniscoid *Mesoniscus graniger* (Verhoeff, 1933). The only published data on the fauna of Polina Peč were reported by Polak (1997). Our investigations on 20.10.2010 and 4.3.2011 resulted in a list of 16 troglobionts (Tabs. 1, 2). This cave is the second known locality for the leptodirine beetle *Prospelaeobates vrezeci* (Fig. 3), previously recorded only from the type locality: the Medvedjak cave. In total, five beetle species, three crustacean, two spider and four false scorpion species were found. We found the cave spider *Stalita taenaria* (Fig. 8) only in the deepest part of the cave with permanently dripping water.

Tab. 1: Checklist of the subterranean fauna of twelve caves in Istria. White Istria: 1 Polina Peč, 2 Račiška Pečina, 3 Dimnice, 4 Medvedjak, 5 Jama Pod Krogom, 7 Rabakova Špilja, 8 Radota Jama; Grey Istria: 6 Kubik, 9 Piskovica; Red Istria: 10 Markova Jama, 11 Jama Kod Burići, 12 Pincinova Jama. Legend: Tb - troglobiont, Tf - troglophile, Tx - trogloxene, Ed - edaphobiont, Par - parasite; * published data only.
Tab. 1: Seznam podzemeljske favne dvanajstih jam v Istri. Bela Istra: 1 Polina peč, 2 Račiška pečina, 3 Dimnice, 4 Medvedjak, 5 Jama pod Krogom, 7 Rabakova špilja, 8 Radota jama; Siva Istra: 6 Kubik, 9 Piskovica; Rdeča Istra: 10 Markova jama, 11 Jama kod Burići, 12 Pincinova jama. Legenda: Tb - troglobiont, Tf - troglofil, Tx - trogloksen, Ed - edafobiont, Par - parazit; * podatek samo iz literature.

Classis / Ordo	Familia (Subfamilia)	Genus, Species (Subspecies)	Status	White Istria	Grey Istria	Red Istria
Gastropoda / Pulmonata	Carychiidae	*Zospeum isselianum* Pollonera, 1887	Tb	1, 3, 6	6	
		Z. kusceri (A. J. Wagner, 1912)	Tb	2, 3*		
		Z. spelaeum schmidti (Frauenfeld, 1854)	Tb	4, 7, 8,	9	10
	Zonitidae	*Oxychilus* (*Oxychilus*) sp.	Tf		9	10, 11
Polychaeta / Canalipalpata	Serpulidae	*Marifugia cavatica* Absolon & Hrabe, 1930	Tb	5		
Clitellata / Haplotaxida	Haplotaxidae	*Haplotaxis* cf. *gordioides* (Hartmann, 1921)	Tf		9	
Clitellata / Hirudinea	Erpobdelidae	*Dina krasensis* Sket, 1968	Tf		9	
Arachnida / Araneae	Dysderidae	*Stalita taenaria* Schiödte, 1848	Tb	2, 3*, 4		
		Stalita sp.	Tb			10, 11
		Mesostalita nocturna (Roewer, 1931)	Tb	8		
	Nesticidae	*Nesticus* cf. *celullans* (Clerk, 1757)	Tf	1	9	
		N. eremita Simon, 1879	Tf	7	6, 9	10, 11, 12
		Nesticus sp.	Tf	5		
	Metidae	*Meta menardi* (Latreille, 1804)	Tf	1, 2		
		Metellina sp.	Tf	2		
	Agelenidae	*Tegenaria* sp.	Tf	2, 6	9	
	Linyphiidae	*Troglohyphantes excavatus* Fage, 1919	Tf	1		
		T. cf. *brignolii* Deeleman-Reinhold, 1978	Tf	2, 3*, 7		
		Troglohyphantes sp.	Tb	8		
		Walckenaeria mitrata (Menge, 1868)	Tx		9	
		Porrhomma cf. *microps* (Roewer, 1931)	Tf		9	
		Leptyphantes sp.	Tf			10, 11
		Diplocephalus cf. *crassiloba* (Simon, 1884)	Tx			10
Arachnida / Pseudoscorpiones	Chthoniidae	*Chthonius spelaeophilus histricus* Beier, 1931	Tb	1, 2, 7, 8		
		Chthonius sp.	Tb		9	11
		Troglochthonius doratodactylus Helversen, 1968	Tb	2, 8		11
	Neobisiidae	*Neobisium spelaeum istriacum* (Müller, 1931)	Tb	1, 2, 3, 4		
		N. reimoseri reimoseri (Beier, 1929)	Tb	2, 7, 8		
		N. reimoseri histricum Beier, 1939	Tb	3*		
		Neobisium sp.	Tb		9	

Classis / Ordo	**Familia (Subfamilia)**	**Genus, Species (Subspecies)**	**Status**	**White Istria**	**Grey Istria**	**Red Istria**
Arachnida / Opiliones	Phalangiidae	*Leiobunum rupestre* (Herbst, 1799)	Tf	1		
	Trogulidae	*Trogulus banaticus* Avram, 1971	Tf	5	6, 9	
Arachnida / Palpigradi	Eukoeneniidae	*Eukoenenia spelea* (Peyerimhoff, 1902)	Tb	4		
		Eukoenenia sp.		7, 8		
Arachnida / Ixodea	Ixodidae	*Eschatocephalus vespertilionis* (Koch, 1844)	Par	3, 7, 8	6	
Arachnida / Mesostigmata	Parasitidae	*Parastitus* sp.	Ed	8		
		Eugamasus cf. *inferus* Willmann, 1941	Ed	3		
	Rhagidiidae	*Rhagidia* sp.	Ed	3	9	
Arachnida / Oribatida	Galumnidae	*Liocarus* sp.	Ed	8		
		Galumna sp.	Ed	8		
	Belbidae	*Belba* sp.	Ed	7		
Arachnida / Prostigmata	Eupodidae	*Linopodes* sp.	Ed		9	
Malacostraca / Amphipoda	Niphargidae	*Hadzia fragilis* S. Karaman, 1932	Tb			12*
		Niphargus stygius (Schiödte, 1847)	Tb	2, 4		
		N. krameri (Schellenberg, 1935)	Tb	3*, 5, 7	6, 9	
		N. steueri steueri Schellenberg, 1935	Tb	5		12
		N. stochi G. Karaman, 1994	Tb	5		
		N. longicaudatus A. Costa, 1851	Tb		9	
		N. cf. *longicaudatus* A. Costa, 1851	Tb			10
		N. hebereri (Schellenberg, 1933)	Tb			12*
Malacostraca / Isopoda	Trichoniscidae (Trichoniscinae)	*Titanethes dahli* Verhoeff, 1926	Tb	1, 2, 3, 4, 5, 8		
		Alpioniscus strasseri (Verhoeff, 1927)	Tb		6, 9	10, 11, 12
		A. cf. *strasseri* (Verhoeff, 1927)	Tb	1, 2, 5, 7		
		Androniscus stygius (Nemec, 1897)	Tb	1, 4		
		A. roseus (C. Koch, 1838)	Tf		6, 9	
		Trichoniscus sp.	Tx		6	
		Hyloniscus sp.	Tx	3		
	Trichoniscidae (Haplophthalminae)	*Haplophthalmus* sp.	Tx		6	
	Trichoniscidae (Thaumatoniscellinae)	*Thaumatoniscellus speluncae* Karaman, Bedek & Horvatović, 2009	Tb	4		
	Mesoniscidae	*Mesoniscus graniger* (Frivaldsky, 1865)	Tf	2*		
	Ligiidae	*Ligidium* sp.	Tx	3		
	Trachelipodidae	*Trachelipus ratzeburgii* (Brandt, 1833)	Tx		9	
		Trachelipus sp.	Tx	7		12
	Agnaridae	*Protracheoniscus* sp.	Tx		6	
	Philosciidae	*Chaetophiloscia* sp.	Tx			12
	Sphaeromatidae	*Monolistra bericum hadzii* Sket, 1959	Tb	7	6	
		Monolistra sp. nov.	Tb		9	12
	Cirolanidae	*Sphaeromides virei virei* Brian, 1923	Tb	5		12

Classis / Ordo	**Familia (Subfamilia)**	**Genus, Species (Subspecies)**	**Status**	**White Istria**	**Grey Istria**	**Red Istria**
Malacostraca / Decapoda	Atyidae	*Troglocaris planinensis* Birštejn, 1948	Tb	5		12
		Troglocaris sp. nov.	Tb			12
Chilopoda / Lithobiomorpha	Lithobiidae	*Eupolybothrus obrovensis* (Verhoeff, 1930)	Tb	1, 3*, 4*, 8		
		Eupolybothrus sp.	Tx	7		
		Lithobius cf. *lapidicola* Meinert, 1872	Tf	7	9	
		L. cf. *erythrocephalus* C. L. Koch, 1847	Tx			12
		Lithobius sp. 1	Tb		9	
		Lithobius sp. 2	Tx	2		
		Lithobiidae indet.	Tx		6	
Chilopoda / Scolopendromorpha	Cryptopidae	*Cryptops* sp.	Ed	2*		12
	Scolopendridae	*Scolopendra cingulata* Latreille, 1789	Tx	7		
Chilopoda / Goephilomorpha	Linotaeniidae	*Strigamia* sp.	Ed		9	
Diplopoda / Glomerida	Trachysphaeridae	*Trachysphaera noduligera* (Verhoeff, 1906)	Tf	7		
		T. cf. *noduligera* (Verhoeff, 1906)	Tf	8		
	Glomeridellidae	*Typhloglomeris* cf. *fiumarana* Verhoeff, 1899	Tb		9	
	Macrosternodesmidae	*Verhoeffodesmus gracilipes* Strasser, 1959	Tb	7	9	
Diplopoda / Chordeumatida	Chordumatidae	*Melogena broelemanni* Verhoeff, 1897	Tx	7*		
	Chordeumatidae	Chordeumatidae indet.	Tx	1		
Diplopoda / Polydesmida	Polydesmidae	*Brachydesmus inferus concavus* Attems, 1898	Tb	3		
		B. subterraneus Heller, 1858	Tf	3, 7	9	12
		Brachydesmus sp.	Tf	4		
Diplopoda / Julida	Julidae	*Typhloiulus illyricus* Verhoeff, 1929	Tb	7	9	12
		Julus sp.	Tx	8	9	
		Julidae indet.	Tx		6	
Entognatha / Diplura	Japygidae	*Japyx* cf. *solifuga* Halliday, 1864	Ed			12
	Campodeidae	*Plusiocampa* cf. *nivea* (Joseph, 1882)	Tb	1, 2, 4, 8		11
Collembola / Entomobryomorpha	Tomoceridae	*Tritomurus scutellatus* Frauenfeld, 1854	Tb	1, 2, 4		
	Paronellidae	*Troglopedetes pallidus* Absolon, 1907	Tb	2, 4, 7, 8	6, 9	10, 11, 12
	Oncopoduridae	*Oncopodura* sp.	Tb	1, 3, 4, 7, 8	6	10, 11
	Entomobrydae	*Pseudosinella* sp.	Tb	3		
		Heteromurus nitidus (Templeton, 1835)	Tf	7, 8		10, 11, 12
	Isotomidae	*Folsomia* sp.	Tx		9	
	Cyphoderidae	*Cyphoderus* sp.	Tx			11
Collembola / Poduromorpha	Onychiuridae	*Onychiurus giganteus* (Absolon, 1901)	Tb	1, 3, 4, 8		
		Onychiurus sp.	Tb		9	
Collembola / Symphypleona	Sminthuridae	*Arrhopalites* sp.	Tx		9	

Classis / Ordo	**Familia (Subfamilia)**	**Genus, Species (Subspecies)**	**Status**	**White Istria**	**Grey Istria**	**Red Istria**
Collembola / Neelipleona	Neelidae	*Neelus* sp.	Tf	4, 8	9	
Insecta / Coleoptera	Carabidae (Trechinae)	*Typhlotrechus bilimeki istrus* (Müller, 1926)	Tb	1, 2, 3, 4, 7		
		Anophthalmus schmidti istriensis Müller, 1909	Tb	1*		
		A. spectabilis istrianus (Ganglbauer, 1913)	Tb	3		
	Carabidae (Sphodrinae)	*Laemostenus cavicola cavicola* Schaum, 1858	Tf	1, 2, 3, 4, 8		
		L. cavicola romualdi J. Müller, 1905	Tf			10, 11, 12
		L. elongatus (Dejean, 1828)	Tx	1*, 2*, 4*		
	Staphylinidae (Pselaphinae)	*Machaerites novissimus* Nonveiller & Pavićević, 2001	Tb	1		
		M. kastavensis Pavićević & Ozimec, 2009	Tb	7, 8		
		Machaerites sp. nov.	Tb		9	
		Pauperobythus globuliventris Nonveiller, Pavićević & Ozimec 2002	Tb			10
		Bryaxis sp.	Tx		9	
		Amaurops sp.	Ed	7		
	Staphylinidae (Staphylininae)	*Atheta spelaea* (Erichson, 1839)	Tf	8		10, 11
		Omalium validum Kraatz, 1857	Tx	1*		
		Staphylinidae indet.	Tx	5	6	
	Cholevidae (Leptodirinae)	*Oryotus schmidti subdentatus* Müller, 1904	Tb	3*		
		Prospelaeobates vrezeci Giachino & Etonti 1996	Tb	2, 4		
		Bathysciotes khevenhuelleri (Miller, 1852)	Tb	2, 7, 8	6, 9	
		Leptodirus hochenwartii reticulatus Müller, 1905	Tb	1*, 2, 3		
	Cholevidae (Cholevinae)	*Choleva* sp.	Tf	5	9	11
	Cholevidae (Platypsellinae)	*Leptinus testaceus* Müller, 1817	Tf	7		
	Curculionidae	*Otiorhynchus* (*Troglorhynchus*) cf. *anophthalmoides anophthalmoides* (Reitter, 1914)	Tf	4		
		Absoloniella sp. n.	Ed/ Tb?	7		
Insecta / Orthoptera	Rhaphidophoridae	*Troglophilus cavicola* (Kollar, 1833)	Tf	1, 2, 3, 4		
		T. neglectus Krauss,1879	Tf	1, 2, 3, 4, 5, 7, 8	6, 9	10, 11, 12*
Insecta / Trichoptera	Limnephilidae	*Micropterna sequax* McLachlan, 1875	Tf	3*		
		Stenophylax sp.	Tf	8		

Classis / Ordo	Familia (Subfamilia)	Genus, Species (Subspecies)	Status	White Istria	Grey Istria	Red Istria
Insecta / Lepidoptera	Tineidae	Tineidae indet.	Tx	8		
	Geometridae	*Triphosa dubitata* (Linnaeus, 1758)	Tf	1, 2, 3, 4, 7		
	Noctuidae	*Scoliopteryx libatrix* (Linnaeus, 1758)	Tf	7	6	
		Hypena obsitalis (Hübner, 1813)	Tf	5		
		Amphipyra effusa (Boisduval, 1828)	Tf	5		
Insecta / Diptera	Limoniidae	*Limonia nubeculosa* Meigen, 1804	Tf		6	
		Limonia sp.	Tf	1, 2, 3, 4, 5	9	10
	Culicidae	*Culex* sp.	Tx	7, 8	9	
	Tipulidae	Tipulidae indet.	Tx	8		
	Mycetophilidae	*Speolepta leptogaster* (Winnertz, 1863)	Tf	1		
Amphibia / Caudata	Proteidae	*Proteus* sp. nov.	Tb			12
Amphibia / Anura	Bufonidae	*Bufo bufo* (Linnaeus, 1758)	Tx			10
	Hylidae	*Hyla arborea* (Linnaeus, 1758)	Tx			10
	Ranidae	*Rana dalmatina* Fitzinger, 1838	Tx			10
Aves / Strigiformes	Strigidae	*Stryx aluco* Linnaeus, 1758	Tx	1*		
Mammalia / Chiroptera	Rhinolophidae	*Rhinolophus ferrumequinum* (Schreber, 1774)	Tf	1, 2, 3*, 4, 7, 8		10
		R. hipposideros (Bechstein, 1800)	Tf	1, 2, 3, 4, 7, 8	6	10
		R. euryale Blasius, 1853	Tf	7*		
	Vespertilionidae	*Barbastella barbastellus* (Schreber, 1774)	Tf	1*, 3*		
		Myotis myotis (Borkhausen, 1797)	Tf	8		10
		M. myotis / M. blythii	Tf	3*		
		M. blythii (Tomes, 1857)	Tf	3*		
		M. capaccinii (Bonaparte, 1837)	Tf	3*		
		M. daubentonii (Kuhl, 1817)	Tf	3		
Mammalia / Rodentia	Gliridae	*Glis glis* (Linnaeus, 1766)	Tx	2, 7		
Mammalia / Carnivora	Mustelidae	*Martes foina* Erxleben, 1777	Tx	1, 2*		

Our discovery of the pseudo-scorpion *Troglochthonius doratodactylus* (Fig. 9) was surprising, since there are no published records of this genus in Slovenia. In the cave, numerous troglophiles and trogloxenes can be found. In autumn (20.10.2010), 13 greater (*Rhinolophus ferrumequinum*) and 42 lesser horseshoe bats (*Rhinolophus hipposideros*) hibernated in the cave.

3. Dimnice

In the past, many naturalists and speleobiologists visited the cave and made a significant contribution to the knowledge about the Dimnice subterranean fauna. The cave is the type locality for *Neobisium spelaeum istriacum*, *Anophthalmus spectabilis istrianus* and *Oryotus schmidti subdentatus*. We visited Dimnice twice (20.10.2010 and 6.3.2011) and added to the list some further troglobionts, now amounting 17 taxa (Tabs. 1, 2). We found a large population of the leptodirine beetle *Leptoditus hochenwartii reticulatus* (Fig. 2). The bat fauna of Dimnice has been regularly monitored since 1991 (Presetnik *et al.,* 2009). During our study we spotted a colony of Daubenton's bats (*Myotis daubentonii*, Fig. 18) overwintering above the water current far from the tourist path. During our permanent temperature measurements we noticed significant temperature fluctuations. In winter the temperature

dropped below 0 °C, causing ice accumulation at the bottom of the entrance pits.

4. Medvedjak

Since its description in 1904, several early cavers and cave beetle collectors (*e.g.*, A. Perko, G. Ravasini, J. Müller) have reported on its beetle fauna. Bat observations have also been published (Presetnik *et al.,* 2009). A new leptodirine genus and species *Prospelaeobates vrezeci* (Giachino & Etonti, 1996) (Fig. 3) was described from this cave. During our investigation we recorded a rich subterranean fauna, counting 15 troglobionts (Tabs. 1, 2). Our finding of the tiny terrestrial isopod *Thaumatoniscellus speluncae* (Fig. 14) is the first record in Slovenia and the third known locality, previously recorded only on Mt. Učka in Istria (Croatia); its closest relatives live in Romania (Bedek *et al.,* 2006, 2011; Karaman *et al.,* 2009).

5. Jama Pod Krogom

We visited the cave twice, on 21.10.2010 and 9.9.2011. Since the cave is active and regularly flooded, the terrestrial subterranean fauna is scarce and consists mainly of troglophiles (Tab. 1). Our finding of the aestivating noctuid moths *Hypena obsitalis* and *Amphipyra effusa* in the entrance chamber is important, because the first one is rarely found in caves, and *Amphipyra* was recorded for the first time in caves, thus showing its sub-troglophilic habits in Slovenia. The cave is one of the most important habitats for the cave tubeworm *Marifugia cavatica* and the cave cirolanid *Sphaeromides virei* (Fig. 12) in south-western Slovenia. Additionally, two species of the amphipod genus *Niphargus*, the cave shrimp *Troglocaris planinensis* and two species of terrestrial isopods - seven troglobionts in total - were recorded in this cave (Tab. 2).

6. Kubik

There are no published data on this cave's fauna, even though it has been recently visited by biologists. We visited the cave on 21.10.2010 and 29.6.2011. The subterranean fauna found in the cave is listed in Table 1. Seven troblobiotic species have been recorded so far (Tab. 2). In the cave the leptodirine beetle *Bathysciotes khevenhuelleri*, the isopode *Alpioniscus strasseri*, two species of Collembola and the cave gastropod *Zospeum isselianum* have been recorded. Among the stygobionts, the amphipod *Niphargus krameri* and the isopod *Monolistra bericum hadzii* (Fig. 13), both endemic to Istria, live in the cave stream. A recent molecular study of *N. krameri* showed the existence of two distinct species in Istria (Fišer, 2011). Despite some old garbage in the cave, the subterranean stream seems not to have been seriously affected by pollution.

7. Rabakova Špilja

This cave is the type locality and up to now had been the only locality of the troglomorphic diplopod *Verhoeffodesmus gracilipes* (Strasser, 1959) (Fig. 11). The cave has also been visited by the Slovene biospeleologists J. Bole (Bole, 1974), F. Velkovrh, B. Sket and N. Mršić (Mršić, 1994) and by the Dutch arachnologist C.R. Deeleman–Reinhold in 1968 (Deeleman-Reinhold, 1978). During our research on 6.7.2010, 26.11.2010, 3.3.2011 and 26.6.2011 at least 13 troglobionts both terrestrial and aquatic, were recorded (Tabs. 1, 2). The small troglomorphic curculionid beetle of the genus *Absoloniella* was found in Croatia for the first time. The specimen

Tab. 2: Number of troglobiotic taxa found in the given Istrian caves. Prevailing habitat of the cave: a - aquatic, t - terrestrial.
Tab. 2: Število troglobiontov, ugotovljenih v raziskovanih istrskih jamah. Prevladujoč habitat jame: a - vodni, t - kopenski.

Region	Cave	Habitat	No. troglobionts
White Istria	Polina peč	t	15
	Račiška pečina	t	16
	Dimnice	a, t	17
	Medvedjak	t	15
	Rabakova špilja	t	13 (14)
	Radota jama	t	15
	Jama pod Krogom	a, t	7
Grey Istria	Piskovica	a, t	15
	Kubik	a, t	7
Red Istria	Markova jama	t	7
	Jama kod Burići	t	7
	Pincinova jama	a, t	11

from Rabakova Špilja is significantly smaller and different in shape, compared to the closely related *Absoloniella reitteri* (J. Müller, 1912) known from caves near Trieste. Since the cave lies in the middle of the village and is easily accessible, it is endangered by organic and inorganic pollution.

8. Radota Jama

Before our surveys on 27.11.2010 and 27.6.2011, the speleobiologists J. Bole and B. Drovenik investigated the cave in 1968 (Bole, 1974) and R. Ozimec in 2001(*unpubl.*). Fifteen troglobiotic taxa have been recorded so far (Tabs. 1, 2). The cave represents one of the few known localities of the cave centipede *Eupolybothrus obrovensis*, the palpigrade *Eukoenenia* sp. (*unpubl.*), the spider *Mesostalita nocturna*, the false scorpion *Troglochthonius doratodactylus* and the beetle *Machaerites kastavensis*. A large wintering colony of the greater mouse-eared bat (*Myotis myotis*) was found in the cave. Because of its remote location and difficulty of access, the cave has not been damaged or polluted.

9. Piskovica

Before our project surveys on 29.11.2010, 3.3.2011 and 27.6.2011, R. Ozimec provided the only intensive studies of the cave fauna in 1998 and 2001 (*unpubl.*). It turned out that both aquatic and terrestrial subterranean faunas are extremely rich and unique. Among the collected specimens, new taxa are in the process of description. Fifteen troglobionts have been found in Piskovica so far (Tabs. 1, 2). The cave is the second known locality of the millipede *Verhoeffodesmus gracilipes*. Additionally, the millipede *Typhloglomeris* cf. *fiumarana* (Fig. 10) recorded in the cave, and known to date only from the Liburnian Karst, represents a significant addition to the subterranean fauna of Istria.

The cave functions as a periodic sinkhole. Organic and inorganic debris are accumulated in the inner parts of the cave by intensive water flow during the rainy season. A serious threat to Piskovica cave is the intention of local inhabitants to exploit the cave for tourism.

10. Markova Jama

Speleobiologically, the cave was first explored in 1997 by members of the Croatian Biospeleological Society. The cave is known as an important site of a large summer maternity colony of the greater mouse-eared bat (*Myotis myotis*), with over 1000 individuals. In the cave, a new genus and species of the troglobiotic pselaphinae beetle *Pauperobythus globuliventris* (Fig. 4) have been found (Nonveiller *et al.,* 2002). Despite our careful research on 28.11.2010 and 29.6.2011 only seven troglobionts were recorded (Tabs. 1, 2). Markova Jama has been protected as a natural geomorphological monument since 1986. Nevertheless, the cave is endangered by organic waste disposal; sheep carcasses were found in the pit before and during our research. The cave fauna is vulnerable, especially the maternity colony of bats, which remains in the cave during spring and summer. For that reason, visits to the cave should be organized only during the period between October and March.

11. Jama Kod Burići

The first speleobiological survey was carried out by members of the Croatian Biospeleological Society in May 2001. On that occasion, the false scorpion *Troglochthonius doratodactylus* was recorded in Croatia for the first time (Ozimec, 2002). During our visits on 29.11.2010 and 28.06.2011, additional species were recorded (Tabs. 1, 2), but only seven among them were troglobionts. Sheep carcasses were found at the bottom of the pit. This put a stop to further exploration. In addition, the cave is critically endangered due to organic waste, especially dead goats and sheep. Besides, the cave fauna is potentially endangered by underground water pollution because of the industry nearby.

12. Pincinova Jama

Since its discovery in 1976, many speleological studies have been carried out in the cave. The endemic Istrian cave salamander *Proteus* sp. nov (Gorički & Trontelj, 2006) and other important stygobionts were found there (Rađa, 1980; Sket, 1994; Zakšek *et al.* 2009). In our visits on 28.6.2011 and 10.9.2011, eight stygobionts were recorded; besides the cave salamander, these were three amphipod species, two aquatic isopod species and two species of cave shrimp (Tab. 1). Since the dry part of the cave is short, only three terrestrial troglobionts were found. Since 1986, Pincinova Jama has received protection as a geomorphological monument. The cave is critically endangered by organic and inorganic pollution. Deposits of garbage are located less than 100 m in front of the cave entrance. At the same distance there is an old quarry, which is still periodically active. Recently the cave was closed off by gates, which are often breached by illegal visitors. A broken gate was also detected during our last visit.

The caves in the carbonate region of White Istria (Čičarija) hosted 44 troglobiotic species, *i.e.*, many more in comparison to the caves in the carbonate littoral region of Red Istria (19 troglobionts) and intermediate flysch Grey Istria (18 troglobionts). According to the Cochran test, the presence of species of subterranean fauna in White Istria differed significantly from both Grey Istria (Q test = 16.20, $p < 0.001$) and Red Istria (Q test = 14.69, $p < 0.001$), while there were no difference between Grey and Red Istria (Q test = 0.04; $p = 0.835$).

DISCUSSION AND CONCLUSIONS

Faunistic investigations of twelve caves in Istria allowed us to estimate and briefly evaluate the species

richness of the subterranean fauna in Istria and to provide some environmental and threat information for these caves. The most important finding was that the division of the Istrian peninsula into three main geomorphological units - the inland White, the Red littoral and the mainly noncarbonate intermediate region of Grey Istria - accurately reflects the distribution of subterranean species as well as species richness.

Caves located in the easternmost part of White Istria, in Matarsko Podolje and Čičarija, are biotically the most diverse. In each of these caves at least 15 troglobiotic taxa were found (Tab. 2). With respect to troglobiotic fauna, some of these caves (Polina Peč, Račiška Pečina, Dimnice, Medvedjak and Radota Jama) can be listed among the richest in the north-western Dinaric region. Given that the troglobiont lists are not complete, since the caves have not been investigated for microfauna and some taxa (*e.g.* copepods, Acarina), the number of troglobiotic species is undoubtedly greater. In contrast with Čičarija, the caves situated in the littoral region of Red Istria (Markova Jama and Jama Kod Burići) are inhabited by troglobiotic fauna only half as rich (Tab. 2). The profusion of troglobiotic fauna in White Istria reflects the close contact of White Istria with the rest of the Dinaric Karst, which is known to be the richest region in the world for subterranean fauna (Sket *et al.*, 2004; Culver *et al.*, 2006; Zagmajster *et al.*, 2008). Most of these troglobionts seem to be endemic to this area. Similar levels of troglobiont richness in the Red and Grey Istria regions and their composition similarity indicate that the flysch areas are also of considerable biospeleological importance. On the other hand, the noncarbonate belt of Grey Istria represents a physical barrier between the littoral Karst and the main Dinaric Karst, resulting in the endemic species and genera of the Red Istria region.

The similarities between the Grey and the Red Istrian subterranean faunas, on the one hand, and their divergence from those of White Istria, on the other, denote the very important role of Grey Istria in geological isolation and in preventing gene flow between the faunas. Other factors could influence differences in species richness among the regions. The Karst in Čičarija has been more fragmented on account of the orography (Otoničar, 2007) and is therefore more extensive in comparison to the more or less flat and unfractured littoral Karst of Red Istria. The climate of the mountainous White Istria region is more humid, providing many more Subsurface Subterranean Habitats (SSHs), like taluses and similar habitats with soil on the surface, in comparison with the more arid lowlands of Red Istria. Humidity in caves is essential for the existence of most terrestrial troglobionts, while, on the other hand, an arid climate is one of the main reasons forcing animals to seek refuge in the subterranean environment.

As result of our investigations, some subterranean taxa were discovered far from their known localities, indicating that their areas are considerably expanded. The new species (subspecies) discovered belong to the crustacean genera *Monolistra* and *Troglocaris* (the Istra phylogroup; Zakšek *et al.,* 2009), the false scorpion *Chthonius* and the *Machaerites, Absoloniella* and *Bathysciotes* beetles. Slovenian fauna has been enriched by the finding of the recently described oniscoid genus and species *Thaumatoniscellus speluncae* (Karaman *et al.*, 2009) in the Medvedjak cave, and the false scorpion genus *Troglochthonius doratodactylus* in the Račiška Pečina cave. In Slovenia, the latter species had previously been found by the Italian biospeleologist Fulvio Gasparo in Štefakova Pečina (No. 1142) near Materija and in Pečina Pod Medvejkom (No. 949) near Sežana (*unpubl.*, courtesy F. Gasparo). New localities have been found for some other troglobionts in Croatia, such as the millipedes *Verhoeffodesmus gracilipes* and *Typhloglomeris* cf. *fiumarana* that significantly extends their known distribution.

We evaluated the potential threats to these caves and their faunas. In large caves, such as the Dimnice cave, occasional visitors do not threaten the cave fauna. On the other hand, organized hikes into smaller caves, such as Polina Peč, Markova Jama and particularly Piskovica, can seriously disturb bat colonies and directly damage the subterranean habitat. The main threat to caves is the disposal of garbage and organic waste in caves. Caves near human settlements, such as Rabakova Špilja, Markova Jama and Jama Kod Burići, are especially threatened. Aquatic cave fauna is endangered by pollution of the underground water draining from the surface. So far, subterranean waters in Jama Pod Krogom, Kubik, Piskovica, Dimnice and Pincinova Jama remain sufficiently clean to host a rich stygobiotic fauna, including the endemic Istrian cave salamander in Pincinova Jama. This cave deserves special attention to avoid potential pollution from a quarry and rubbish dump in the near vicinity.

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PODZEMELJSKA FAVNA DVANAJSTIH JAM V ISTRI

Slavko POLAK
Zavod Znanje, OE Notranjski muzej Postojna, SI-6230 Postojna, Kolodvorska c. 3
E-mail: slavko.polak@notranjski-muzej.si

Jana BEDEK & Roman OZIMEC
Hrvaško biospeleološko društvo (HSBD), HR-10000 Zagreb, Demetrova 1, Hrvaška

Valerija ZAKŠEK
Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za biologijo, SI-1000 Ljubljana, Večna pot 111

POVZETEK

V prispevku so zbrani literaturni podatki o podzemeljski favni dvanajstih jam v Istri in rezultati lastne natančne inventarizacije teh jam. Raziskava je bila opravljena v okviru projekta Karst Underground Protection v letih 2010 in 2011. Izbrane jame so v različnih predelih Istre in se razlikujejo med seboj po okoljskih dejavnikih, po tem, da je v njih le kopenska ali tudi vodna favna ter po različni stopnji ogroženosti jam in favne zaradi človeške dejavnosti. Za raziskavo smo izbrali naslednje jame v Sloveniji: Polina peč, Račiška pečina, Medvedjak, Dimnice, Jama pod Krogom in Kubik ter na Hrvaškem: Radota špilja, Rabakova jama, Markova jama, Jama kod Burići, Pincinova jama in Piskovica. Izkazalo se je, da so glede števila troglobiontov – vrst, specializiranih za življenje v podzemlju – jame na območju Čičarije (Bela Istra) več kot dvakrat bogatejše (44 vrst) od jam v Sivi Istri (18) in litoralnem območju Rdeče Istre (19). V posameznih jamah v Čičariji živi po 15 vrst troglobiontov ali več; te vrste so večinoma ozko sorodne s favno bližnjega severozahodno dinarskega območja. V dveh jamah Rdeče Istre je bilo najdenih po 7 troglobiontov. Jama pod Krogom in Pincinova jama sta pomembni zlasti kot habitat številnih vodnih troglobiontov – stigobiontov. Jame, nastale na kontaktu apnencev in fliša v nekraški Sivi Istri, so se izkazale za nepričakovano bogate s troglobionti. Nekatera odkritja so bila presenetljiva in predstavljajo pomemben prispevek k poznavanju razširjenosti nekaterih vrst in rodov podzemeljskih živali. V prispevku prvič objavljamo podatek o prisotnosti podzemeljskega paščipalca Troglochthonius doratodactylus v Sloveniji. Prav tako je bil podzemeljski enakonožni rak – mokrica Thaumatoniscellus speluncae – v Sloveniji najden prvič. Najdba podzemeljskih dvojnonog Vehoeffodesmus gracilipes in Typhloglomeris cf. fiumarana v jami Piskovica predstavljata znatno povečanje znanih območij njune razširjenosti. Majhen hrošč ril-

čkar iz rodu Absoloniella sp. je bil prvič najden na ozemlju Hrvaške. Med podzemeljskimi raki, pajkovci in hrošči je bilo nekaj taksonov že prepoznanih kot novih za znanost; njihovi znanstveni opisi so v pripravi. Za raziskane jame smo ovrednotili ekološke razmere ter ocenili sedanje in potencialne vire ogrožanja jam ter njihove favne. Ugotovili smo, da so nekatere jame organsko in anorgansko onesnažene zaradi nelegalnega odlaganja smeti in kadavrov domačih živali, potencialno pa tudi zaradi kamnolomov v bližini. Zaradi možnosti onesnaževanja podtalnih voda je še potencialno ogrožena vodna favna jam. Med potencialne grožnje favni štejemo tudi nenadzorovano nabiranje favne v jamah in v nekaterih primerih prepogost obisk jam.

Ključne besede: podzemeljsko živalstvo, troglobionti, varstvo jam, Istra

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PLATE I: Some representatives of the Istrian subterranean fauna photographed during the study.
TABLA I: Nekateri predstavniki istrskega podzemeljskega živalstva, fotografirani med raziskavo
Photograph credits / Avtorji fotografij: RO – Roman Ozimec, SP – Slavko Polak, JB – Jana Bedek.
Fig. 2 / Sl. 2: *Leptodirus hochenwartii reticulatus* ***(SP)***
Fig. 3 / Sl. 3: *Prospelaeobates vrezeci* ***(SP)***
Fig. 4 / Sl. 4: *Pauperobythus globuliventris* ***(RO)***
Fig. 5 / Sl. 5: *Typhlotrechus bilimeki istrus* ***(SP)***
Fig. 6 / Sl. 6: *Onychiurus giganteus* ***(RO)***
Fig. 7 / Sl. 7: *Plusiocampa* ***cf.*** *nivea* ***(SP)***
Fig. 8 / Sl. 8: *Stalita taenaria* ***(RO)***
Fig. 9 / Sl. 9: *Troglochthonius doratodactylus* ***(SP)***

PLATE II: Some representatives of the Istrian subterranean fauna photographed during the study. Photographs credits as in Plate I.
TABLA II: Nekateri predstavniki istrskega podzemeljskega živalstva, fotografirani med raziskavo. Avtorji fotografij kot na Tabli I.
Fig. 10 / Sl. 10: *Typhloglomeris* ***cf.*** *fiumarana* ***(RO)***
Fig. 11 / Sl. 11: *Verhoeffodesmus gracilipes* ***(RO)***
Fig. 12 / Sl. 12: *Sphaeromides virei virei* ***(SP)***
Fig. 13 / Sl. 13: *Monolistra bericum hadzii* ***(JB)***
Fig. 14 / Sl. 14: *Thaumatoniscellus speluncae* ***(JB)***
Fig. 15 / Sl. 15: *Zospeum spelaeum schmidti* ***(SP)***
Fig. 16 / Sl. 16: *Triphosa dubitata* ***(SP)***
Fig. 17 / Sl. 17: *Myotis daubentonii* ***(SP)***

PLATE I/TABLA I

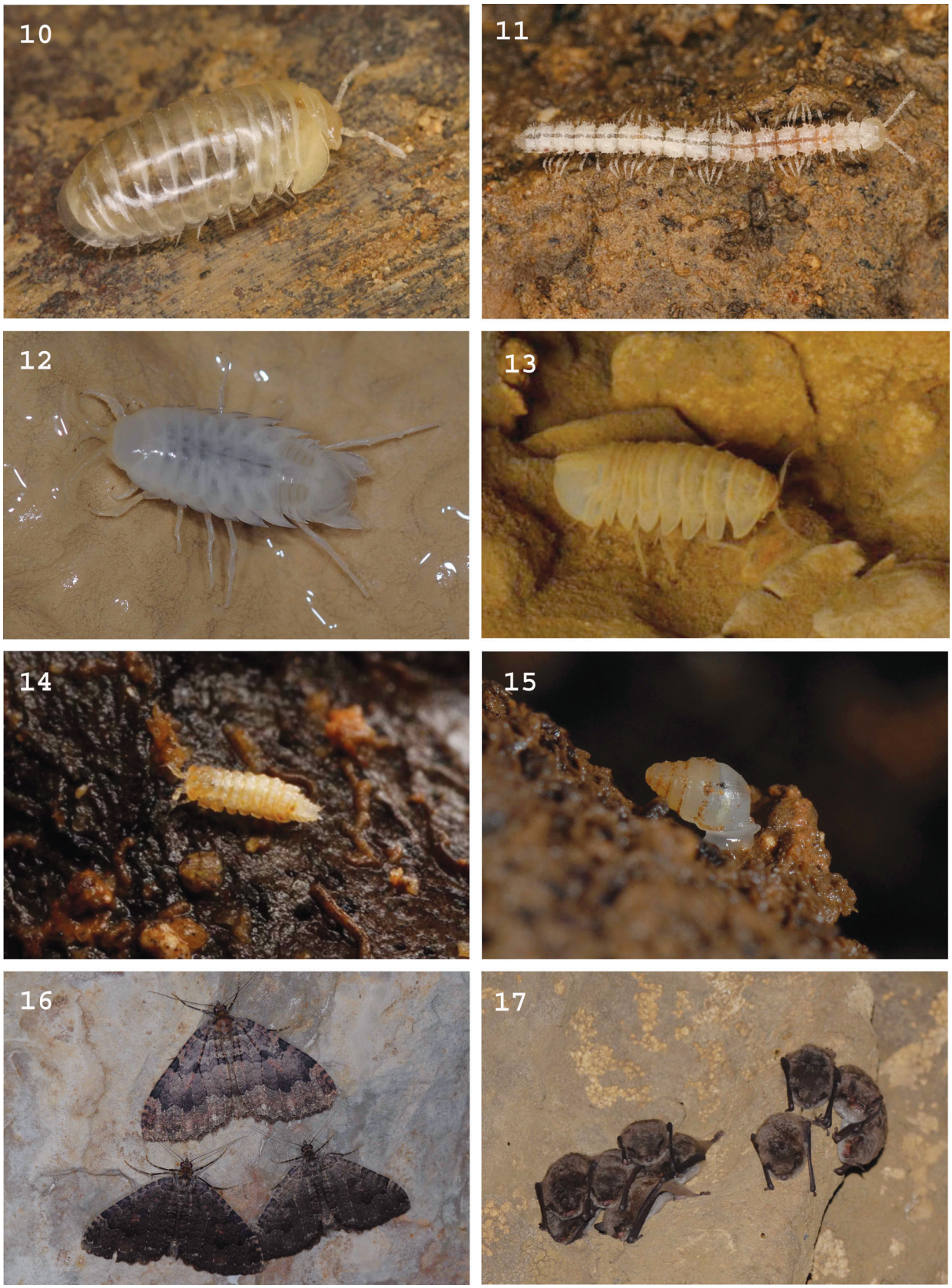

PLATE II/TABLA II

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NEW DATA ON THE PRESENCE OF THREE SIMILAR SPECIES OF THE GENUS *MELITAEA: M. ATHALIA, M. AURELIA* AND *M. BRITOMARTIS* (LEPIDOPTERA: NYMPHALIDAE) IN THE NORTH-WESTERN BALKANS

Toni KOREN & Jure JUGOVIC

University of Primorska, Science and Research Centre, Institute for Biodiversity Studies, SI-6310 Izola, Giordana Bruna 6, Slovenia
E-mail: koren.toni1@gmail.com

ABSTRACT

The recently collected distribution data about three similar Melitaea *(Lepidoptera: Nymphalidae) species (*M. athalia*,* M. aurelia *and* M. britomartis*) that were reliably identified based on morphology of genitalia are presented. Three countries from the NW Balkans (Slovenia, Croatia, and Bosnia and Herzegovina) were included in the survey. All three species are widely distributed in Slovenia and Croatia from the lowlands to the subalpine belt, frequently occurring also in sintopy. The proportion of* M. aurelia *and* M. britomartis *that are often treated as rare is quite high, accounting for 28.5 % and 22.7 % of the total studied sample size, respectively. The known area of distribution for* M. aurelia *and* M. britomartis *has been significantly extended to the south, especially in Croatia from where only two records for the latter had previously existed.* M. britomartis *is recorded in Bosnia and Herzegovina for the first time.*

Key words: *Melitaea athalia/aurelia/britomartis*, genitalia, distribution, Slovenia, Croatia, Bosnia and Herzegovina

NUOVE CONFERME DELLA PRESENZA DI TRE SPECIE SIMILI DEL GENERE *MELITAEA: M. ATHALIA, M. AURELIA* E *M. BRITOMARTIS* (LEPIDOPTERA: NYMPHALIDAE) NEI BALCANI NORD-OCCIDENTALI

SINTESI

L'articolo riporta recenti dati sulla distribuzione di tre specie simili di Melitaea *(Lepidoptera, Nymphalidae:* M. athalia*,* M. aurelia *e* M. britomartis*), che sono state determinate in base alla morfologia degli organi genitali. La ricerca ha coperto il territorio di tre stati dei Balcani nord-occidentali (Slovenia, Croazia, Bosnia ed Erzegovina). I risultati indicano che tutte le specie hanno un'ampia distribuzione in Slovenia e Croazia.* M. aurelia *e* M. britomartis*, frequentemente considerate quali specie rare, hanno rappresentato un'alta percentuale del campione studiato, ossia il 28,5 % ed il 22,7 %, rispettivamente. L'area di distribuzione conosciuta di* M. aurelia *e* M. britomartis *è stata estesa significativamente verso sud, specialmente in Croazia, dove fino ad oggi si contavano solo due segnalazioni delle specie studiate.* M. britomartis *è stata trovata in Bosnia ed Erzegovina per la prima volta.*

Parole chiave: *Melitaea athalia/aurelia/britomartis*, genitali, distribuzione, Slovenia, Croazia, Bosnia ed Erzegovina

INTRODUCTION

The genus *Melitaea* is comprised of about 65 small to medium-sized butterfly species distributed widely across the Palaearctic region (Leneveu et al., 2009). The radiation of diversity in the genus *Melitaea* is estimated to have happened in early the Miocene, somewhere in the Central Palaearctic region (Leneveu et al., 2009). In Europe, 15 species of the genus *Melitaea* are present (Van Swaay et al., 2010), of which eight are distributed in the area of the north-western part of the Balkan Peninsula. Most European representatives of this genus have clearly visible external diagnostic morphological characteristics and can be easily distinguished from similar species (Tolman & Lewington, 2008). Aside from those, this genus also includes some species which are difficult to recognize by external morphology, *i.e.* colour patterns on the wings. There are some species for which the morphology of the genitals must be checked for correct identification (Urbahn, 1952; Tolman & Lewington, 2008; Paulavičiūtė & Tamutis, 2009). This includes the complex of three species present in the northern Balkans: *Melitaea athalia* (Rottemburg, 1775), *Melitaea aurelia* (Nickerl, 1850) and *Melitaea britomartis* Assmann, 1847. Although some authors propose different external character keys for identification of the three species (*e.g.*, Higgins & Rilley, 1970; Lafranchis, 2004; Tolman & Levington, 2008), *i.e.* combination of coloration (lunules on hind wings and band coloration, colour of hair on the palps and size), the morphological variability prevents proper identification at all times (Tolman & Lewington, 2008; Lorković, 2009).

The three most north-western Balkan countries (Slovenia, Croatia and Bosnia and Herzegovina) have a long tradition of butterfly research (*e.g.,* Mann, 1857, 1867, 1869; Hafner, 1909; Stauder, 1919–1927; Carnelutti, 1992; Lelo, 2007; Lorković, 2009; Šašić & Mihoci, 2011). Until 1991, all three countries were part of former Yugoslavia. So far only one distribution atlas for the whole area of Yugoslavia exists (Jakšić, 1988) where the presence of each species is indicated for the 10 x 10 km^2 UTM fields. Slovenia is the best surveyed country in the Balkans, owing to numerous recent publications, and a new Atlas of butterflies (Verovnik *et al.*, 2012). In the last 20 years much new data regarding the butterflies of Croatia has been published (*e.g.,* Mihoci *et al.*, 2007; Koren & Ladavac, 2010; Koren *et al.*, 2011; Šašić & Mihoci, 2011), but large parts of the country still remain unsurveyed. For Bosnia and Herzegovina, only a small number of papers have been published in the last 20 years (*e.g.,* Lelo, 2000), including a book with general information on the distribution of butterflies in this country (Lelo, 2007). While *M. athalia* and *M. aurelia* have already been recorded in Bosnia and Herzegovina, this is not true for *M. britomartis* (Lelo, 2007).

The majority of the published data on the three species of *Melitaea* from the NW Balkans rely mostly on identification based on external morphology. Since the latter is extremely difficult owing to the high rate of morphological variability in species (and/or population) (Tolman & Lewington, 2008), there is a high probability of a series of misidentifications in the older literature, most commonly in favour of *M. athalia* which is believed to be the most widespread and frequent of all three species (Jakšić, 1988; Lorković, 2009). As such, distribution data from papers in which species were identified only on the basis of external morphological characteristics needs to be treated differently from the data obtained from genitalia preparations. Without those data, however, almost no records would be left for Croatia and Bosnia and Herzegovina. With the application of identification based on the morphology of genitalia, we expect: (1) to reliably identify the specimens to the species rank, and (2) to provide exact data on their geographical, altitudinal and temporal distributions. Hence, we expect to considerably change the current knowled-

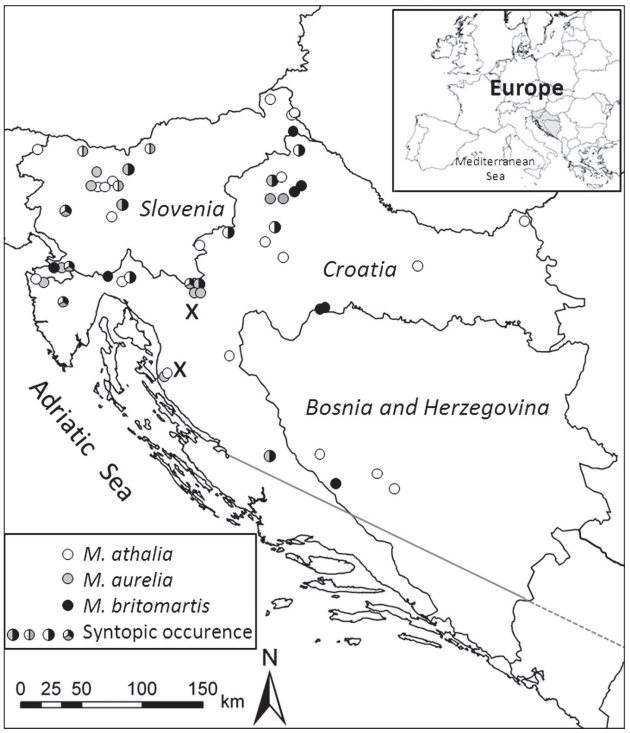

Fig. 1: Distribution of the three** Melitaea **species (**M. athalia, M. aurelia, M. britomartis**) from the NW Balkans based on the data included in the present study. The historically defined southern limit of the distribution of** M. aurelia **is denoted by the grey line. The two historical records of** M. britomartis **in Croatia are denoted by "X". Sl. 1: Zemljevid razširjenosti treh vrst iz rodu** Melitaea **(**M. athalia, M. aurelia, M. britomartis**) na področju SZ Balkana. Zgodovinsko postavljena južna meja razširjenosti** M. aurelia **je označena s sivo črto. Dva zgodovinska podatka za** M. britomartis **na Hrvaškem sta označena z "X".

ge on the presence of these three species in some parts of the NW Balkans.

MATERIALS AND METHODS

Samples of three species of the genus *Melitaea* (Fig. 1, Appendix 1) were collected with a butterfly net for over last 30 years all over the NW Balkans, including the following countries: Slovenia (samples from 20 localities), Croatia (32 localities) and Bosnia and Herzegovina (4 localities). Sample size ranged from 1 to 12 for males and from 1 to 3 for females, with males prevailing (Appendix 1). On each sampling occasion, the data on sampling locality was gathered, which includes geographic position, altitude and a short habitat description (Appendix 1). Specimens were mounted and are deposited in two private collections in Pazin, Croatia (Koren T. collection) and Kranj, Slovenia (Jugovic I. collection) (see Appendix 1, under Coll.).

As a high morphological variability of the wing size, pattern and coloration has been reported by several studies (*e.g.,* Tolman & Lewington, 2008), no specimens were attributed to a single species regarding these characteristics (see Introduction for details). Specimens were identified to the species level according to the genitalia structure that is species specific (Urbahn, 1952; Tolman & Lewington, 2008; Paulavičiūtė & Tamutis, 2009). A completely certain identification, however, is possible only in males (Urbahn, 1952). In females there are slight differences among the species, but not all specimens can be reliably attributed to the species level (Urbahn, 1952). The genitalia of each specimen were isolated using the standard procedure for genitalia isolation. The procedure includes the cutting of the abdomen and immersing it in a 10 % KOH solution overnight. Isolated genitalia were examined under a stereomicroscope (Leica MZ 12.5) and stored in 75 % ethanol afterwards. The storage vials are vouchered accordingly to specimens from the collections.

All sampling localities were geo-referenced either by using a GPS device (e-Trex Vista) or by the use of Google Earth afterwards (Appendix 1). For the distribution and statistical analyses, ArcGIS software, Excel 2010 (Microsoft) and SPSS 14.0 were used, respectively.

RESULTS

Species and geographic occurrence

The principal result of our analysis is the confirmation of the expected presence of all three species in Slovenia, Croatia and Bosnia and Herzegovina (Fig. 1). Of 123 collected specimens, 60 (48.8 %) belong to *M. athalia* (32 localities), followed by 35 specimens (28.5 %) of *M. aurelia* (23 localities) and 28 specimens (22.7 %) of *M. britomartis* (21 localities). The distribution of all three species seems to be more or less contiguous, and the distribution areas of the all three species greatly overlap (Fig. 1). Nevertheless, all three species were found together only at 7.1 % of all localities, and in an additional 21.4 %, two species were found in sintopy. In other cases, only one species was found in a single locality (Appendix 1).

Temporal and altitudinal distribution

The temporal and altitudinal occurrence phenology of the three studied *Melitaea* species is presented in Figure 2. The adults are active from the beginning of May until the end of July. Nevertheless, the presence of *M. aurelia* was not recorded in approximately the first third of the season (*i.e.,* first record is from 8th of June from Šterna in Croatian Istria).

Specimens of all three studied species of *Melitaea* were found from the lowlands (< 100 m. a.s.l.) to the subalpine zone, as high as 1600 m a. s. l., with a shortened period of occurrence at higher elevations, especially on account of the time delay at the beginning of the season. The seasonal occurrence of each of the three species is positively correlated with altitude, meaning that the higher the altitude, the later the data on the first occurrence of *Melitaea*. For all three species pooled together, Pearson's correlation coefficient between the altitude and the date of record ($r = 0.55$) is statistically significant at $p < 0.001$. There is no statistically significant difference (ANOVA, $p > 0.05$) either between the species and dates of recordings, or between the species and altitude.

DISCUSSION

Reliable notes on the geographic distribution of the *Melitaea* species for each of the three countries of the

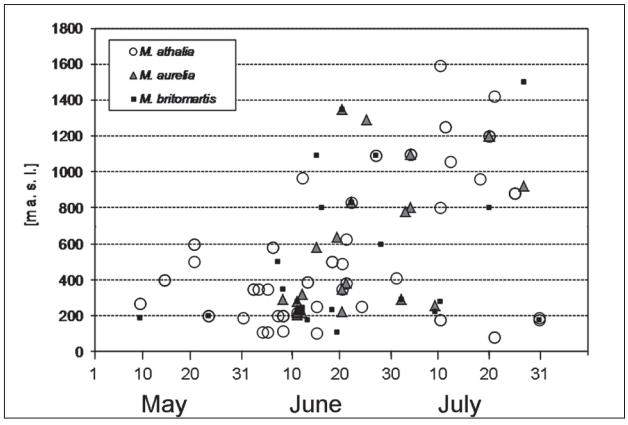

Fig. 2: Temporal and altitudinal occurrence of three** Melitaea **species (**M. athalia, M. aurelia, M. britomartis**) from the NW Balkans.
Sl. 2: Sezonsko in višinsko pojavljanje odraslih živali treh vrst iz rodu** Melitaea **(**M. athalia, M. aurelia, M. britomartis**) na področju SZ Balkana.

NW Balkans are scarce due to lack of genitalia-based identification. Nevertheless, the distribution area of all three *Melitaea* species has been shown to be scattered across the whole region. Their wide distribution area was to be expected because most of the feeding plants of the *Melitaea* species (Tolman & Lewington, 2008) are common and widespread in the Balkans. Some of the primary feeding plants (Jonko, 2012) are common for all three species (*e.g., Plantago* spp. and *Veronica* spp. for all the three, with an addition of *Melampyrum nemorosum* for *M. athalia/aurelia*); secondary food plants of *M. athalia* (Jonko, 2012) are also *Valeriana officinalis*, *Polygonum bistorta* and *Centaurea* spp. *M. athalia* is therefore the least specialized of the *Melitaea* species from the NW Balkans. Nevertheless, the proportion of the other two species is somewhat higher than might be expected, and they are by no means rare or local (as suggested by some authors, *e.g.,* Lorković, 2009). There is an indication, however, that in some localities *M. aurelia* or *M. britomartis* can be the dominant (or the only) species of the complex (Appendix 1).

Our sampling covered the whole season of the flight period of the three species. According to Tolman & Levington (2008) the flight period for *M. athalia and M. aurelia* lasts during June and July, and for *M. britomartis*, from late May/Early June until end of July/early August. Our data correspond to the mentioned literature, however the flight period starts earlier in the NW Balkans for *M. athalia* and *M. britomartis*. Although two generations have been reported for *M. britomartis* in some southern localities (*e.g,*. the Ticino Valley in NW Italy; Tolman & Lewington, 2008), no gap between the (two) generations could be seen from our data. According to data from Slovenia (Verovnik *et al.*, 2012), *M. aurelia* and *M. britomartis* fly in a single generation from mid-May until the end of July, with a distinctive peak in the second half of June for the latter. For *M. aurelia*, also a partial second generation was recorded in the Vipava Valley (Verovnik *et al.*, 2012). Adults of *M. athalia*, however, appear mostly in two partially overlapping generations from late April until September, with few fresh specimens observed in September and October that probably belong to a partial third generation (Verovnik *et al.*, 2012).

Our results indicate that the altitudinal distribution of the studied species in the NW Balkans is broader than mentioned from the literature (Tolman & Lewington, 2008; Verovnik *et al.*, 2012): *M. athalia*: 0–800 m a.s.l., occasionally even above 2000 m a.s.l. (Verovnik *et al.*, 2012); *M. aurelia*: 100–1500 m a.s.l. (1600 m: Verovnik *et al.*, 2012); *M. britomartis*: 300–900 m a.s.l. (1250 m: Verovnik *et al.*, 2012). While the data obtained for *M. athalia* and *M. aurelia* are within the already published range, we found *M. britomartis* from 110 up to 1500 m a.s.l. For *M. britomartis*, we can report that the highest known locality from Slovenia was at an elevation of 1350 m a.s.l. (Ambrož Pod Krvavcem, Kamniško Savinjske Alpe), and the absolute highest elevation from Bosnia and Herzegovina was at an elevation of 1500 m a.s.l. (Troglav Mountain, The Dinarides).

Additional notes on geographic distribution

For Bosnia and Herzegovina, Lelo (2007) reports the country-wide distribution of *M. athalia*, except for the small area in the south-eastern Mediterranean part. According to the same author, *M. aurelia* inhabits the central mountainous part of the country. No data on the presence of *M. britomartis* exists for the country (Lelo, 2000, 2007), or for the wider area of southern part of the NW Balkans (*e.g.,* Jakšić, 1988). Hence, our record from the Bosnian part of Troglav Mountain, Vještić Gora is the first record of this species for Bosnia and Herzegovina. This specimen was collected on dry grassland at the beginning of the hiking path toward the highest peak, Troglav. Only one specimen was observed and collected. Additionally, we would expect that *M. britomartis* is also present in NW Bosnia as it was observed in Croatia in the Hrvatska Kostajnica region, only a few kilometres from the Bosnian border. Thus we predict that its range in Bosnia and Herzegovina is possibly much wider. With this addition and the recent record of *Proterebia afra* (Koren & Trkov, 2011) the butterfly fauna of Bosnia and Herzegovina now includes 192 butterfly species.

As no recent atlas about the butterflies of Croatia exists, the information on the distribution could be discerned from the atlas of the butterflies of Yugoslavia (Jakšić, 1988), and recent faunistic studies (*e.g.,* Mihoci *et al.*, 2007; Koren *et al.*, 2011). According to Jakšić (1988), *M. athalia* is widespread in Croatia which is in line with our survey. Regarding *M. aurelia*, 42 records for Croatia exist (Bohatsch, 1892; Rebel, 1895; Koča, 1900; Abafi-Aigner, 1910; Grund, 1916; Gussich, 1917: Lorković & Mladinov, 1971; Mladinov, 1973; Cribb, 1976; Goossens-Cromphrout & Goossens-Cromphrout, 1982; Kranjčev, 1985; Hafner, 1994; Mihoci *et al.*, 2007; Marčec, 2008; Ábraham, 2008; Lorković, 2009; Koren & Ladavac, 2010; Koren *et al.*, 2011) but the means of identification are not clearly stated.

Regarding the presence of *M. britomarits* in Croatia, Jakšić (1988) mentions only one locality, in the area of Josipdol near Ogulin in NW Croatia. This record was originally published by Mann (1867), and was later only cited by Abafi-Aigner *et al.* (1896) and Jakšić (1988). Mihoci *et al.* (2007) report *M. britomartis* from the Velebit Mountains, Švica. In this survey *M. britomartis* was collected from 15 different localities (Appendix 1) across Croatia. This indicates a much wider distribution than was previously known. With the addition of our data, we expand the known distribution of *M. britomartis* in Croatia to different regions, including Istria, Dalmatia, Zagorje, Međimurje and Slavonija. It seems that *M. britomartis* is missing from eastern Slavonia and south-eastern Dalmatia, but as those areas were not sufficiently surveyed, the possibility exists that it will be recorded there.

CONCLUSIONS

In the case of the three studied *Melitaea* species, for which their variability sometimes renders them almost impossible to identify using only external morphology, investigating the genitalia morphology is an irreplaceable tool. Our survey has showed that: (1) *M. athalia* is widespread in the whole researched area; (2) *M. aurelia* is more common and widespread than was previously known, especially in Croatia, and (3) *M. britomartis* is widespread in the surveyed regions of Slovenia and Croatia, and was recorded also in Bosnia and Herzegovina. All three species are widely distributed from lowlands to the mountainous belt, frequently occurring also in sintopy. The proportion of *M. aurelia* and *M. britomartis* that are often treated as rare is quite high, accounting for 28.5 % and 22.7 % of total sample size, respectively.

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NOVI PODATKI O RAZŠIRJENOSTI TREH PODOBNIH VRST IZ RODU *MELITAEA, M. ATHALIA, M. AURELIA* IN *M. BRITOMARTIS* (LEPIDOPTERA: NYMPHALIDAE), NA PODROČJU SEVEROZAHODNEGA BALKANA

Toni KOREN & Jure JUGOVIC

Univerza na Primorskem, Znanstveno-raziskovalno središče, Inštitut za biodiverzitetne študije, SI-6310 Izola, Giordana Bruna 6
E-mail: koren.toni1@gmail.com

POVZETEK

V prispevku so zbrani podatki o razširjenosti treh podobnih vrst iz rodu Melitaea *(Lepidoptera: Nymphalidae) na področju SZ Balkana. V raziskavo smo vključili podatke iz treh držav: Slovenije, Hrvaške ter Bosne in Hercegovine. V preteklih 30 letih je bilo zbranih 123 osebkov metuljev treh podobnih vrst, navadnega pisančka (*M. athalia*), jetičnikovega pisančka (*M. aurelia*) in temnega pisančka (*M. britomartis*). Čeprav za pomoč pri razlikovanju med temi vrstami obstajajo opisi njihove zunanje morfologije in določevalni ključi, smo ugotovili, da visoka morfološka (znotraj- in medvrstna) raznolikost ne omogoča zanesljive določitve. Genitalne preparate smo pripravili za vse živali, vključene v analizo, in jih zanesljivo določili do vrste. Ugotovili smo, da so vse tri vrste razmeroma pogoste, čeprav navadni pisanček s skoraj polovico (48,8 %) vseh analiziranih živali prevladuje. Preostali vrsti sta približno enako zastopani z 28,5 % (*M. aurelia*) in 22,7 % (*M. britomartis*). Vse tri vrste se pogosto pojavljajo sintopo, najdemo pa lahko tudi lokalitete, kjer smo zabeležili vse tri skupaj. Razširili smo znano vertikalno razširjenost za temnega pisančka v Sloveniji do višine 1350 m (Ambrož pod Krvavcem, Kamniško-Savinjske Alpe), sicer pa do višine 1500 m (Troglav, Bosna in Hercegovina). Podatek s Troglava je obenem tudi najjužnejši podatek za to vrsto na območju SZ Balkana in prva najdba za Bosno in Hercegovino. Tudi na Hrvaškem smo znano območje razširjenosti te vrste močno razširili, saj je bila do sedaj (določena na podlagi zunanje morfologije) na Hrvaškem znana le z dveh lokalitet.*

Ključne besede: *Melitaea athalia/aurelia/britomartis*, genitalije, razširjenost, Slovenija, Hrvaška, Bosna in Hercegovina

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***Appendix 1: Data on sampling localities of three** Melitaea **species** (M. athalia, M. aurelia, M. britomartis) **from the NW Balkans. Legend: SN = sample number, BIH = Bosnia and Herzegovina, CRO = Croatia, SLO = Slovenia), X, Y = GPS coordinates, M = number of males, F = number of females, Coll. = collection (TK = Toni Koren, JuI = Ivan Jugovic): data for leg. and det. the same, except for cases denoted with asterisk (*), where leg. J. Premrl.*
Priloga 1: Podatki o vzorčnih lokalitetah za tri vrste iz rodu** Melitaea (M. athalia, M. aurelia, M. britomartis) **s področja SZ Balkana. Legenda: SN = številka vzorca, BIH = Bosna in Hercegovina, CRO = Hrvaška, SLO = Slovenija, X, Y = GPS koordinate, M = število samcev, F = število samic, Coll. = zbirka (TK = Toni Koren, JuI = Ivan Jugovic): podatki za leg. in det. enaki, razen v primerih, označenih z zvezdico (*), kjer je leg. J. Premrl.

SN	Country	Locality	X	Y	Date	Altitude (m)	Habitat	Syntopic occurence	Gender	Coll.
Melitaea athalia										
1	BIH	Kupres, Demirovac	5683172	4876659	11.7.1988	1250	mountain grassland		1M, 1F	JuI
2	BIH	Makljen, mountain pass	5709025	4861175	12.7.1988	1060	mountain grassland		1M, 0F	JuI
3	BIH	Šator, Međugorje	5632681	4890062	21.7.2011	1420	mountain grassland		0M, 1F	TK
4	CRO	Grdanjci, Samobor	5549483	5076453	10.7.2010	175	wet grassland	*M. britomartis*	2M, 0F	TK
5	CRO	Ivanščica, hiking path	5586114	5118082	12.6.2011	967	dry grassland		1M, 0F	TK
6	CRO	Obruč, hiking path »Pod planinu«	5458566	5029635	13.6.2010	390	dry grassland		1M, 1F	TK
7	CRO	Papuk, toward Klinovac	5709760	5041569	21.6.2011	624	woodland edge		1M, 0F	TK
8	CRO	Peščenica, Velika Gorica	5591311	5051891	15.6.2009	105	woodland edge		1M, 0F	TK
9	CRO	Platak, Planinarski dom	5466155	5031809	27.6.2001	1090	alpine grassland	*M. britomartis*	2M, 0F	TK
10	CRO	Plitvice	5547652	4967041	10.7.1988	-	wet grassland		1M, 0F	JuI
11	CRO	Plovanija, Istra	5393198	5035042	5.6.2011	111	dry grassland		1M, 0F	TK
11	CRO	Plovanija, Istra	5393198	5035042	4.6.2011	111	dry grassland		1M, 0F	TK
12	CRO	Skoblić Brdo, Bosiljevo	5523865	5030113	11.6.2011	215	dry grassland	*M. aurelia, M. britomartis*	1M, 0F	TK
13	CRO	Šenkovec, Čakovec	5609093	5142392	30.7.2011	175	wet grassland	*M. britomartis*	0M, 1F	TK
14	CRO	Vela Traba, Pazin	5411485	5012008	2.6.2008	350	dry grassland	*M. aurelia, M. britomartis*	2M, 0F	TK
14	CRO	Vela Traba, Pazin	5411485	5012008	3.6.2008	350	dry grassland	*M. aurelia, M. britomartis*	0M, 1F	TK
14	CRO	Vela Traba, Pazin	5411485	5012008	5.6.2008	350	dry grassland	*M. aurelia, M. britomartis*	0M, 1F	TK
14	CRO	Vela Traba, Pazin	5411485	5012008	20.6.2009	350	dry grassland	*M. aurelia, M. britomartis*	1M, 0F	TK
15	CRO	Velebit, Zavižan	5498251	4961973	10.7.2002	1594	alpine grassland		0M, 1F	TK
16	CRO	Vugrovec, Zagreb	5586762	5081473	8.6.2008	200	dry grassland	*M. britomartis*	1M, 0F	TK
16	CRO	Vugrovec, Zagreb	5586762	5081473	24.5.2009	200	dry grassland	*M. britomartis*	3M, 0F	TK
16	CRO	Vugrovec, Zagreb	5586762	5081473	7.6.2010	200	dry grassland	*M. britomartis*	1M, 0F	TK
16	CRO	Vugrovec, Zagreb	5586762	5081473	8.6.2010	200	dry grassland	*M. britomartis*	1M, 1F	TK
17	CRO	Zagreb, Savski nasip	5573958	5071307	8.6.2001	112	wet grassland		1M, 0F	TK
18	CRO	Zmajevac, Baranja	5797019	5081041	21.7.2011	80	dry grassland		0M, 2F	TK

19	CRO	Žumberak, Pilatovci	5523549	5062242	20.6.2009	490	woodland edge		1M, 0F	TK
20	SLO	Bobovek, Kranj	5450705	5125738	15.5.1988	400	grassland		0M, 3F	Jul
21	SLO	Šenčur, near airport Ljubljana	5456256	5121139	21.6.1992	380	grassland & shrubs	*M. aurelia*	1M, 0F	Jul
22	SLO	Bukovnica, Bukovniško jezero	5602357	5171252	31.5.1991	190	cultivated grassland		1M, 0F	Jul
23	SLO	Čaven	5409270	5088045	4.7.1992	1100	dry grassland	*M. aurelia, M. britomartis*	2M, 1F	Jul
24	SLO	Črna na Koroškem	5487586	5146958	6.6.2002	580	woodland edge	*M. aurelia*	1M, 1F	TK
25	SLO	Grad, Goričko	5582925	5184520	10.5.1992	270	-		2M, 0F	Jul
26	SLO	Strmec, Mangart, Julijske Alpe	5393091	5142528	18.7.1992	960	mountain grassland		0M, 1F	Jul
27	SLO	Kobilje, Murska Sobota	5605131	5172643	30.7.1993	190	wet grassland		0M, 1F	Jul
28	SLO	Pševo, Kranj	5447330	5122012	21.5.1972	500	cultivated grassland		0M, 1F	Jul
28	SLO	Pševo, Kranj	5447330	5122012	18.6.1984	500	cultivated grassland		1M, 1F	Jul
29	SLO	Slavnik	5419065	5045274	22.6.1991	830	dry grassland	*M. aurelia, M. britomartis*	0M, 1F	Jul
30	SLO	Smrekovec	5455326	5084255	15.6.2002	248	-		2M, 0F	TK
31	SLO	Stražišče, Kranj	5447596	5120616	1.7.1984	410	-		0M, 1F	Jul
32	SLO	Završnica	5435616	5142011	20.7.1984	1200	mountain grassland	*M. aurelia*	3M, 1F	Jul
Melitaea aurelia										
33	CRO	Grabrk, Bosiljevo	5522898	5024839	11.6.2011	230	wet grassland		1M, 0F	TK
34	CRO	Klimen, Konščina	5590333	5106635	11.6.2010	220	wet grassland	*M. britomartis*	1M, 0F	TK
34	CRO	Klimen, Konščina	5590333	5106635	20.6.2009	220	wet grassland	*M. britomartis*	1M, 0F	TK
35	CRO	Lomska Duliba, Velebit	5501560	4959268	25.6.2009	1292	alpine grassland		1M, 0F	TK
36	CRO	Mali Komor, Zagorje	5579587	5106815	9.7.2011	255	dry grassland		0M, 1F	TK
37	CRO	Novi Golubovec, Zagorje	5576317	5114684	12.6.2011	320	dry grassland		1M, 1F	TK
38	CRO	Orišje, Bosiljevo	5522896	5029172	12.6.2011	215	dry grassland	*M. britomartis*	1M, 0F	TK
12	CRO	Skoblić Brdo, Bosiljevo	5523865	5030113	11.6.2011	215	dry grassland	*M. athalia, M. britomartis*	1M, 0F	TK
39	CRO	Šterna, Istra	5404566	5030623	8.6.2011	293	dry grassland		1M, 0F	TK
40	CRO	Varoš, Bosiljevo	5522522	5029364	11.6.2011	206	dry grassland		1M, 0F	TK
14	CRO	Vela Traba, Pazin	5411485	5012008	20.6.2009	350	woodland edge	*M. athalia, M. britomartis*	1M, 0F	TK
41	CRO	Zrmanja Vrelo, Gračac	5513001	4895146	2.7.2010	290	-	*M. britomartis*	0M, 1F	TK
21	SLO	Šenčur, near airport Ljubljana	5456256	5121139	21.6.1992	380	grassland & shrubs	*M. athalia*	0M, 1F	Jul
23	SLO	Čaven	5409270	5088045	4.7.1992	1100	dry grassland	*M. athalia, M. britomartis*	1M, 0F	Jul
24	SLO	Črna na Koroškem	5487586	5146958	15.6.2002	580	dry grassland	*M. athalia*	1M, 0F	TK
42	SLO	Črni kal	5412693	5045611	26.5.1975	-	dry grassland		1M, 0F	Jul*
43	SLO	Dom v Dragi, Draga, Begunje	5439927	5138585	4.7.1993	800	grassland		0M, 1F	Jul

44	SLO	Javornik, Kranj	5445746	5121595	19.6.1994	640	cultivated grassland		1M, 0F	Jul
45	SLO	Ambrož, Krvavec, Kamniške Alpe	5463371	5126537	20.6.1992	1350	grassland & shrubs	*M. britomartis*	1M, 0F	Jul
46	SLO	Sv. Jošt, Kranj	5446049	5122185	3.7.1995	780	grassland		1M, 0F	Jul
29	SLO	Slavnik	5419065	5045274	22.6.1991	830	dry grassland	*M. athalia, M. britomartis*	2M, 0F	Jul
47	SLO	Vremščica	5426322	5060845	27.7.1995	920	dry grassland		1M, 0F	Jul
48	SLO	Zadvor, Ljubljana	5468719	5099919	11.6.2011	280	woodland edge	*M. britomartis*	1M, 0F	TK
32	SLO	Završnica	5435616	5142011	20.7.1984	1200	alpine grassland	*M. athalia*	9M, 1F	Jul
Melitaea britomartis										
49	BIH	Troglav, Vještić Gora	5629438	4865960	27.7.2011	1500	alpine grassland		1M, 0F	TK
4	CRO	Grdanjci, Samobor	5549483	5076453	13.6.2011	175	wet grassland	*M. athalia*	1M, 0F	TK
50	CRO	Hrvatska Kostajnica	5618449	5009397	19.6.2011	110	dry grassland		1M, 0F	TK
51	CRO	Jovac, Hrvatska Kostajnica	5616039	5004984	18.6.2011	235	wet grassland		1M, 0F	TK
34	CRO	Klimen, Konščina	5590333	5106635	11.6.2011	220	wet grassland	*M. aurelia*	1M, 0F	TK
38	CRO	Orišje, Bosiljevo	5522896	5029172	12.6.2011	215	dry grassland	*M. aurelia*	1M, 0F	TK
52	CRO	Pažurovec, Zagorje	5591436	5110791	9.7.2011	220	dry grassland		0M, 1F	TK
9	CRO	Platak, Planinarski dom	5466155	5031809	15.6.2002	1090	mountain grassland	*M. athalia*	1M, 0F	TK
9	CRO	Platak, Planinarski dom	5466155	5031809	27.6.2002	1090	mountain grassland	*M. athalia*	1M, 0F	TK
53	CRO	Podrute, Novi Marof	5596886	5113393	10.7.2011	280	woodland edge		1M, 0F	TK
54	CRO	Radoboj, Malogorski	5571673	5114812	12.6.2011	245	dry grassland		1M, 0F	TK
55	CRO	Rupa, Rijeka	5443502	5038328	7.6.1982	500	dry grassland		1M, 0F	Jul*
12	CRO	Skoblić Brdo, Bosiljevo	5523865	5030113	11.6.2011	215	dry grassland	*M. athalia, M. aurelia*	2M, 0F	TK
13	CRO	Šenkovec, Čakovec	5609093	5142392	30.7.2011	175	wet grassland	*M. athalia*	1M, 0F	TK
14	CRO	Vela Traba, Pazin	5411485	5012008	8.6.2008	350	dry grassland	*M. athalia, M. aurelia*	1M, 0F	TK
16	CRO	Vugrovec, Zagreb	5586762	5081473	24.5.2010	200	dry grassland	*M. athalia*	1M, 0F	TK
41	CRO	Zrmanja Vrelo, Gračac	5585027	4895475	2.7.2010	290	wet grassland	*M. aurelia*	1M, 0F	TK
23	SLO	Čaven	5409270	5088045	19.6.1978	800	dry grassland	*M. athalia, M. aurelia*	1M, 0F	Jul*
23	SLO	Čaven	5409270	5088045	28.6.1982	600	dry grassland	*M. athalia, M. aurelia*	0M, 1F	Jul*
45	SLO	Ambrož, Krvavec, Kamniške Alpe	5463371	5126537	20.6.1992	1350	grassland & shrubs	*M. aurelia*	0M, 1F	Jul
29	SLO	Slavnik	5419065	5045274	22.6.1991	830	dry grassland	*M. athalia, M. aurelia*	3M, 1F	Jul
29	SLO	Slavnik	5419065	5045274	16.6.1969	800	dry grassland	*M. athalia, M. aurelia*	1M, 0F	Jul*
56	SLO	Veščica, Ormož	5597409	5153326	10.5.1992	190	wet grassland		1M, 0F	Jul
48	SLO	Zadvor, Ljubljana	5468719	5099919	11.6.2011	280	woodland edge	*M. aurelia*	1M, 0F	TK

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SURVEY ON *CHAMELEA GALLINA* BEDS IN THE LIGNANO AREA (GULF OF TRIESTE, ADRIATIC SEA)

Stefano BIONDI & Donatella DEL PIERO

Department of Life Sciences, University of Trieste, I-34127 Trieste, Via L. Giorgieri 10, Italy
E-mail: delpiero@units.it

ABSTRACT

*Following the mass mortality which occurred in 1996, the rebuilding of the Striped Venus clam (*Chamelea gallina*) stock was complicated due to recruitment failure and low growth rate, as suggested by seasonal surveys. Thin sections of shell were obtained from twenty clams randomly extracted for every survey and it was observed that the cleft was formed in the autumn as ascertained in previous surveys. Stock management based on minimum size and quantities only is discussed. At present, in spite of the efforts to manage the population made by both the Public Authority and fishermen soon after 1996, the depletion of the area is almost complete as resulted from surveys done in 2009 and 2011.*

Keywords: *Chamelea gallina*, Gulf of Trieste, growth, clam fishery, management

INDAGINE SU *CHAMELEA GALLINA* NELL'AREA DI LIGNANO (GOLFO DI TRIESTE, MARE ADRIATICO)

SINTESI

*La vongola comune (*Chamelea gallina*), risorsa ampiamente sfruttata nel corso degli anni, ha subito nel 1996 una moria particolarmente disastrosa ed estesa lungo le coste adriatiche. Questo ha in parte ostacolato la piena realizzazione dell'autonomia gestionale da parte dei Consorzi di gestione con lunghi periodi di fermo pesca, ma ha anche messo in evidenza che la ripresa dello stock è stata pesantemente influenzata sia dal reclutamento, sia dal tasso di crescita, che sembra aver subito vistosi rallentamenti negli anni immediatamente successivi al fenomeno, imponendo una riflessione sulle modalità di sfruttamento. Di fatto la situazione è precipitata a partire dal 2009, ed il declino è confermato dai rilievi speditivi effettuati nel 2011.*

Parole chiave: *Chamelea gallina*, Golfo di Trieste, crescita, pesca di vongole, gestione

INTRODUCTION

The Striped Venus clam (baby clam) *Chamelea gallina* (L. 1758), widely distributed along European coasts (Fischer *et al.*, 1987) has long been a very important resource on the western Adriatic coast. This species is also exploited in Spain and Morocco (Ramon & Richardson, 1992), Portugal (Gaspar *et al*., 2004; Rufino *et al.*, 2010) and in Turkey (Alpbaz & Temelli, 1997). In Italy, the fishery is facing a long decline which had already started during the 1980s and is still in progress, as reported by, *e.g.*, Romanelli *et al.* (2009). Froglia (1989) indicates a maximum of 100,000 tons in estimated landings and the 2010 last SISTAN official report (www.irepa.org/index.php?option=com_phocadownload&view=category&id=57&Itemid=52&lang=it, visited 24 March 2012) estimates only 21,794 metric tons. The quantity referred to the hydraulic dredges sector (the razor clam *Ensis minor*, *C. gallina* and the Smooth Venus *Callista chione*). The clam fishery in the Adriatic has been studied since the early 1980s thanks to a program financed by the Italian government involving many scientific teams. At the time, concern was on the rise regarding possible stock depletion (*e.g.*, Froglia, 1975, 1989; Bombace, 1985).

In the Gulf of Trieste, the species distribution and exploitation pattern were and still are quite different from those of the other maritime districts and the species may now be found from the coast line only to a depth of 5 m. Up to 1994, many vessels of the Monfalcone District were fishing *C. gallina* in the Venice District and *E. minor* was exploited instead. For that reason the *C. gallina* exploitation history in the Gulf of Trieste cannot be compared to the rest of Adriatic (Del Piero, 1994, 1998; Del Piero *et al*., 1998). From the beginning of the scientific surveys the stock in the Gulf of Trieste was subject to significant changes and the worst change was induced by the mass mortality which occurred in 1996 (Anonymous, 1997; Del Piero, 1998; Froglia, 2000; Romanelli *et al.*, 2009, among others) along the whole western Adriatic coast. Over the last few years, a partial recovery was observed in 2007 (D. Del Piero, *pers. observation*) followed by a depletion in 2009 (1.1 ind. m^{-2} at Lignano) (Burca *et al*. 2010; de Flego, 2011) and confirmed after the surveys done in 2011 (no clams collected at Lignano; D. Del Piero, *pers. observation*). The 2011 campaign however, was designed to evaluate the commercial fraction only.

This paper presents the data collected in the Lignano area from November 1997 (soon after the mass mortality) to February 2000 (nine surveys) where a strong depletion in the commercial fraction (≥ 25 mm) was observed together with a slowing in the clam growth, compared to the previous years. The study was financed by the national Agriculture Ministry (1997/98 and 1999/2001) and the 2009 and subsequent surveys were done in force of the Agreement between the Fishermen Consortium (CO.GE.MO) of the Monfalcone Maritime District and the Life Science Department.

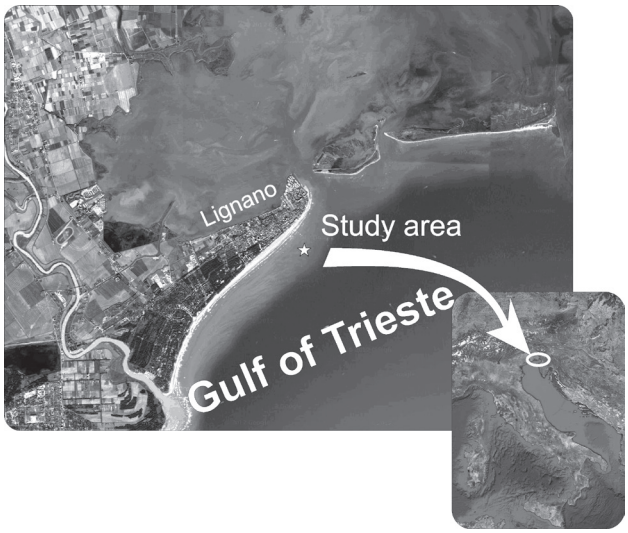

Fig. 1: Schematic map of sampled area (courtesy Dr. P. Rossin, ARPA-FVG).
Sl. 1: Shematični prikaz območja vzorčenja (avtor: dr. P. Rossin, ARPA-FVG).

MATERIAL AND METHODS

The samples were collected in front of Lignano, Gulf of Trieste (Fig. 1) by a commercial fishing vessel of Marano Lagunare equipped with a modified hydraulic dredge (Del Piero, 1994) during experimental tows from a depth of 2 to 6 meters (1 m intervals). The tow length was fixed at 50 m, except for November 1997, when the scarcity of clams suggested a 100 m length instead. The modified dredge has three sectors and the central one is 78 cm wide with a 6 mm gap among steel bars in order to collect individual clams ≥ 1 cm (C. Froglia, *pers. comm.*). Only the clams lying in the central section were sampled and frozen in the laboratory at -18 °C. The measurements were done on individuals using vernier callipers to the smallest mm and the frequency classes were fixed at 1 mm in amplitude.

The frequency classes over 25 individuals were pair-tested with Kolmogorov-Smirnov (Sokal & Rohlf, 1997) in order to evaluate the probability that they were extracted from the same statistical population. Based on past experience (Scaricci, 1995-96; Keller *et al.*, 2002) it was decided to study thin sections from the samples collected at a depth of 4 m.

Twenty individuals were extracted using a random process, re-measured to the second decimal and the right valve, after inclusion in *Araldite*®, was sectioned along the umbo-ventral axis in the laboratory of the Department of Geological, Environmental and Marine Sciences (DISGAM and now the Department of Mathematics and Geosciences) and sections of 30-40 µm were obtained (M. Cafau, *pers. comm.*). In the Microscopy Laboratory of the Department of Mathematics and Geo-

sciences, the sections were examined for age evaluation based on the occurrence of the V-shaped structure (Fig. 2) generally known as the cleft (Ramon & Richardson, 1992; Gaspar *et al.*, 2004) that involves all the carbonate strata of the aragonitic shell of *C. gallina*. The aragonitic form of calcium carbonate in *C. gallina* had previously been ascertained (F. Princivalle, *pers. comm.*). The carbonate layers are: a) the superior composite prismatic layer, b) the crossed lamellar layer and the innermost so-called homogeneus layer (Alemany, 1986). The cleft

Tab. 1: *Chamelea gallina* ***density (ind. m^{-2}) and frequency distribution (cm); in italic: 1999 cohort.***
Tab. 1: Gostota vrste *Chamelea gallina* ***(ind. m^{-2}) in frekvenčna porazdelitev (cm); v kurzivu: kohorta iz leta 1999***

cm	Nov 97	Feb 98	Jun 98	Feb 99	Apr 99	May 99	Jul 99	Nov 99	Feb 00
0.5								*0.545*	*0.083*
0.6								*0.571*	*0.090*
0.7								*0.474*	*0.096*
0.8								*0.378*	*0.212*
0.9								*0.468*	*0.449*
1	0.017	0.082	0.314	0.051	0.051	0.031	0.156	0.551	0.468
1.1	0.030	0.110	0.558	0.141	0.046	0.062	0.168	0.186	0.269
1.2	0.049	0.123	0.622	0.167	0.062	0.108	0.168	0.135	0.263
1.3	0.017	0.069	0.596	0.154	0.082	0.174	0.261	0.090	0.179
1.4	0.017	0.051	0.404	0.115	0.072	0.221	0.321	0.090	0.071
1.5	0.015	0.041	0.449	0.154	0.067	0.272	0.433	0.071	0.083
1.6	0.017	0.067	0.282	0.147	0.036	0.277	0.381	0.045	0.083
1.7	0.059	0.064	0.353	0.173	0.051	0.174	0.447	0.077	0.096
1.8	0.074	0.108	0.429	0.167	0.046	0.195	0.399	0.064	0.090
1.9	0.099	0.136	0.750	0.199	0.103	0.210	0.324	0.045	0.122
2	0.111	0.190	0.917	0.147	0.067	0.123	0.247	0.058	0.103
2.1	0.062	0.172	0.955	0.096	0.056	0.113	0.197	0.071	0.051
2.2	0.057	0.123	0.987	0.064	0.077	0.046	0.138	0.058	0.128
2.3	0.025	0.090	0.949	0.038	0.062	0.041	0.091	0.109	0.083
2.4	0.007	0.038	0.840	0.026	0.031	0.036	0.038	0.122	0.109
2.5	0.005	0.013	0.660	0.077	0.021	0.031	0.035	0.135	0.186
2.6	/	0.003	0.295	0.064	0.021	0.031	0.018	0.115	0.038
2.7	0.005	/	0.128	0.032	0.026	0.031	/	0.109	0.058
2.8	0.002	0.003	0.077	0.064	0.026	0.015	0.015	0.096	0.026
2.9	0.005	/	0.038	0.045	0.015	0.036	0.013	0.083	0.026
3	0.005	0.003	0.013	0.013	0.015	0.026	0.007	0.058	0.006
3.1	/	0.003	0.013	0.032	/	/	/	0.051	/
3.2	/	0.003	0.006	/	0.005	/	/	0.064	0.006
3.3	/	/	0.006	/	/	/	/	0.032	/
3.4	/	/	/	/	/	/	0.005	/	/
3.5	0.002	0.003	0.013	/	/	/	/	0.013	/
3.6	/	0.003	/	/	/	/	/	0.019	/
3.7	0.002	/	/	/	/	/	/	/	/
3.8	/	0.005	/	/	/	/	/	0.006	/
3.9	/	/	/	/	/	/	/	/	/
Total	0.683	1.500	10.654	2.167	1.036	2.251	3.861	2.551	2.545

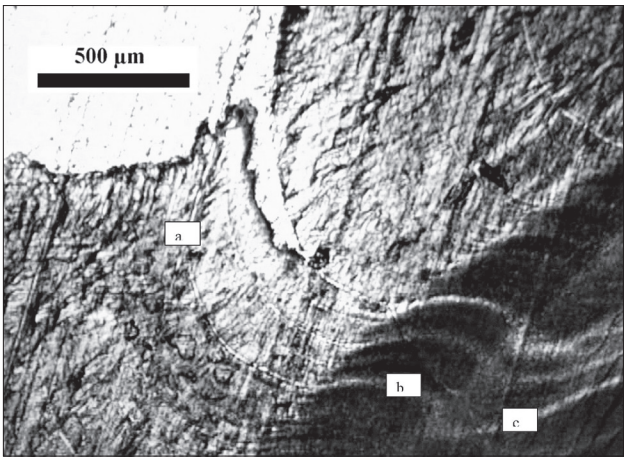

Fig. 2: Cleft detail of** Chamelea gallina **(100x, photomicrography courtesy of Prof. Valli). Section from umbo to ventral margin (left valve) of a 18 mm in length specimen. The brighter area is the a) superior prismatic sub-layer; growth increments are visible in b) inferior crossed lamellar sub-layer and in the c) homogeneous layer.
Sl. 2: Detajl zajede pri vrsti** Chamelea gallina **(100x, fotomikrografija, avtor: prof. Valli). Predel od vrha lupine do trebušnega roba (leva lupina) pri primerku, dolgem 18 mm. Svetlejši predel je a) zgornji prizmatični podsloj, vidijo se prirastki; b) spodnji prečni lamelarni podsloj; c) homogeni sloj.

in the northern Adriatic is formed in fall, generally at the end of October or the beginning of November (Scaricci, 1995-96) and the same pattern was observed by Ramon & Richardson (1992) and Gaspar *et al.* (2004) for Spain and Portugal.

RESULTS AND DISCUSSION

The overall density is reported in Table 1, average length and standard deviation in Table 2, the cleft number in the thin sections are shown in figure 3.

November 1997. Overall density resulting after pooling the four hauls were 0.68 ind. m^{-2} only. Frequency distributions after the Kolmogorov-Smirnov test differ significantly and so are not reported in Table 3, where only non significant differences are shown. From the 20 thin sections, only 17 were suitable for age evaluation, even after sectioning the left valve. The results are summarized in figure 3 where it can be observed that 5 specimens from 15.05 to 18.85 mm have only one cleft, 7 from 19.3 and 20.9 mm have 2 clefts, 3 have 3 clefts and the 30.05 mm individual shows 4 clefts.

February 1998. Clams were found in all five tows, overall density is 1.5 ind. m^{-2}. One cleft was present in clams from 12.55 to 15.40 mm in length, 2 clefts in 3 clams from 16.55 to 22.15 mm. Clams from 22.55 to 23 55 mm exhibit 3 clefts.

Tab. 2: Sample mean length (avg., in cm) and standard deviation (s^2).
Tab. 2: Povprečna dolžina vzorca (avg., v cm) in standardni odklon (s^2).

	Depth (m)	2	3	4	5	6
Nov 97	avg.	3.09	2.07	2.00	1.32	
	s^2	0.506	0.305	0.235	0.244	
Feb 98	avg.	2.68	2.11	2.00	1.34	1.07
	s^2	0.854	0.262	0.249	0.281	0.040
Jun 98	avg.	2.33	2.01	1.33		
	s^2	0.341	0.371	0.190		
Feb 99	avg.	2.53	2.22	1.66	1.44	
	s^2	0.346	0.273	0.134	0.121	
Apr 99	avg.	2.12	2.06	1.87	1.37	
	s^2	0.691	0.585	0.440	0.245	
May 99	avg.	1.86	2.01	1.54		
	s^2	0.403	0.439	0.237		
Jul 99	avg.	2.05	1.74	1.52	1.23	
	s^2	0.387	0.350	0.257	0.314	
Nov 99	avg.	2.93	2.46	1.26	1.23	
	s^2	0.402	0.417	0.290	0.044	
Feb 00	avg.	2.30	2.21	1.48		
	s^2	0.395	0.427	0.495		

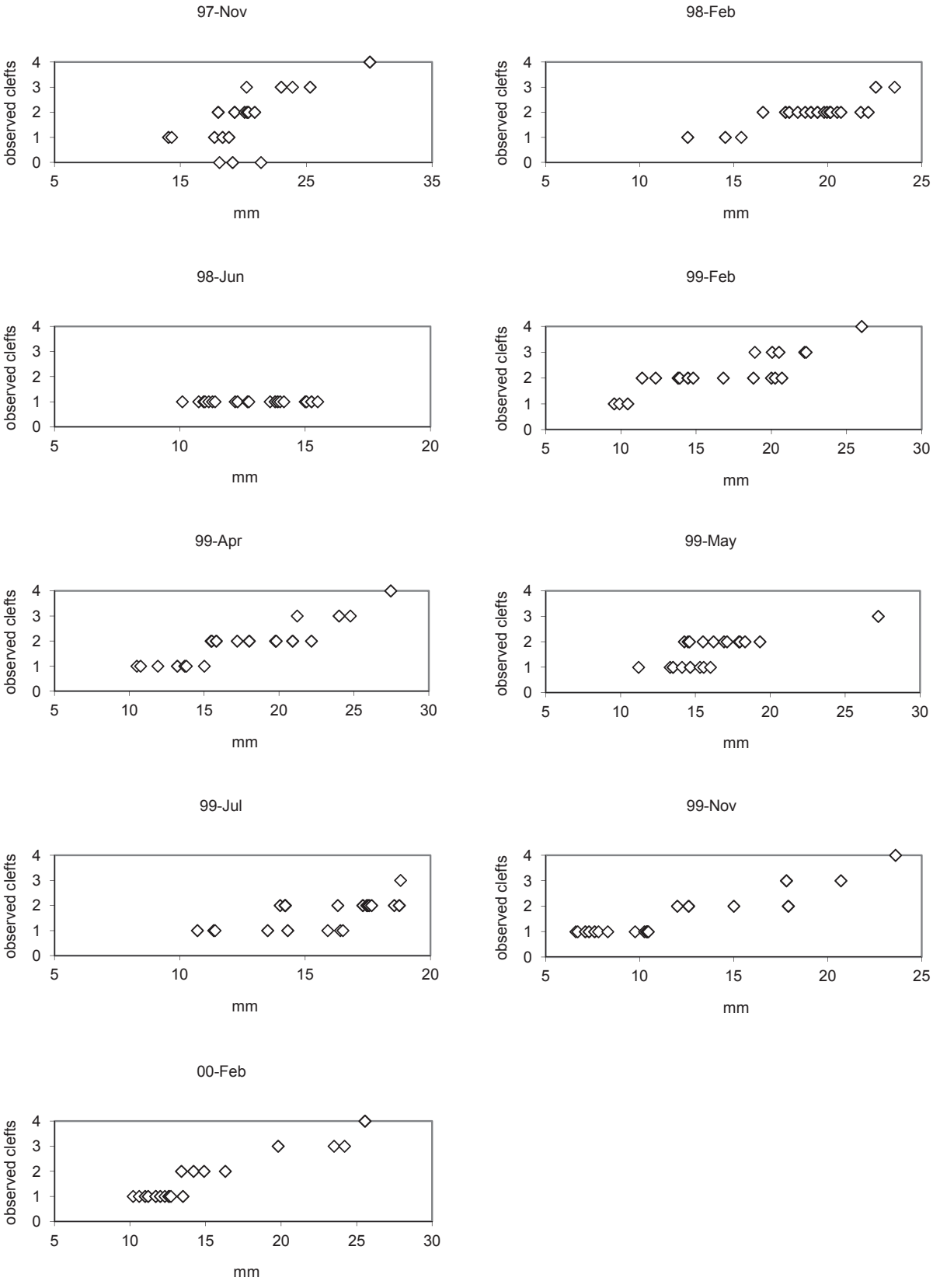

Fig. 3: Length in mm and cleft numbers observed in the samples.
Sl. 3: Dolžina v mm in število zajed pri vzorčnih primerkih.

June 1998. Clams were found in three samples, overall density is 14.11 ind. m^{-2}, the majority being undersized. All the individuals in the third sample were from 10.1 to 15.5 mm in length, a quite anomalous result and so only the growth after cleft formation was observed.

February 1999. Due to the emergence of serious bureaucratic problems mainly involving insurance protocols, the surveys were suspended in 1998 and restarted in February 1999. The clams were found in 4 samples and the overall density was estimated at 2.17 ind. m^{-2}. All the thin sections revealed a cleft near or proximate to the shell margin. From the samples obtained in this survey, it emerged that clams very close in length may account for different ages, *e.g.* 2 or 3 years.

April 1999. Data were referred to four hauls and the overall density was 1.04 ind. m^{-2}. The frequency distributions obtained from sample 2 and 3 (Tab. 3) were not significantly different ($D_{0.05} = 0.234$, $D_{max} = 0.226$). One cleft (Fig. 3) was present in individuals from 10.5 to 15 mm. In the interval between 14.45 and 22.15 mm, two specimens had 2 clefts but one clam 21.2 mm in length had 3 clefts.

May 1999. Another survey was done in May and three samples were obtained. The overall density was estimated at 2.25 ind. m^{-2} and the littlest individual observed with 2 clefts was 14.10 mm in length, the largest with one cleft was 16.00 mm (Fig.3).

July 1999. Clams were found in four samples and the density was 3.86 ind. m^{-2}, higher than previously found. One cleft was observed in clams from 10.7 to 16.3 mm, 2 were present in specimens from 16.40 and 17.55 mm, and 3 between 18.55 and 18.75 mm.

November 1999. The results were referred to four samples and the estimated density was less: 2.55 ind. m^{-2}. All the sectioned clams had a cleft near the shell margin, in 12 of 20; the marginal cleft was very close to the margin. The clams in the interval 6.60 and 10.40 had only one cleft, 2 clefts were found in clams from 12.00 and 17.90 mm, 3 in two clams 17.8 and 20.7 mm in length. Four clefts were observed in the largest clam measuring 23.6 mm.

February 2000. The last survey was done and the clams were collected in only three hauls, with 2.54 ind. m^{-2} estimated density. The first cleft was present in 12 specimens (Fig. 3) (10.20-13.50 mm in length), 2 clefts were observed in clams from 13.40 and 16.30 mm, 3 were present in clams between 19.80 and 24.20 mm in length. The only clam with 4 clefts was 25.50 mm in length.

The nine surveys done on the Lignano clam beds outline alternate results, the maximum density being observed in June 1998, two years after the mass mortality. The low densities generally observed in autumn and winter may be an effect of clams burrowing due to low temperatures (the same happens in summer to avoid heat). The 1997 results (when low densities were observed) seem to indicate that the depletion caused by the 1996 mortality was far from being recovered. Beyond seasonal variation within the sample amounts, the fishery was suspended in the Monfalcone Maritime District very early in 1997 (February) until January 1998. The data obtained from the February 1998 survey show

Tab. 2: Sample mean length (avg., in cm) and standard deviation (s^2).
Tab. 2: Povprečna dolžina vzorca (avg., v cm) in standardni odklon (s^2).

	Depth (m)	**2**	**3**	**4**	**5**	**6**
Nov 97	avg.	3.09	2.07	2.00	1.32	
	s^2	0.506	0.305	0.235	0.244	
Feb 98	avg.	2.68	2.11	2.00	1.34	1.07
	s^2	0.854	0.262	0.249	0.281	0.040
Jun 98	avg.	2.33	2.01	1.33		
	s^2	0.341	0.371	0.190		
Feb 99	avg.	2.53	2.22	1.66	1.44	
	s^2	0.346	0.273	0.134	0.121	
Apr 99	avg.	2.12	2.06	1.87	1.37	
	s^2	0.691	0.585	0.440	0.245	
May 99	avg.	1.86	2.01	1.54		
	s^2	0.403	0.439	0.237		
Jul 99	avg.	2.05	1.74	1.52	1.23	
	s^2	0.387	0.350	0.257	0.314	
Nov 99	avg.	2.93	2.46	1.26	1.23	
	s^2	0.402	0.417	0.290	0.044	
Feb 00	avg.	2.30	2.21	1.48		
	s^2	0.395	0.427	0.495		

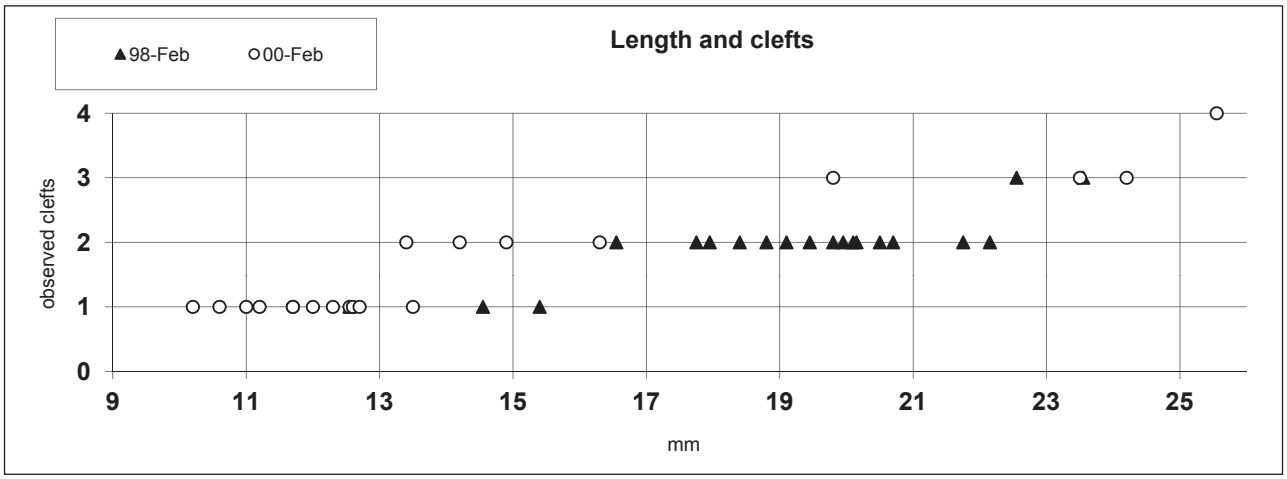

Fig.4: Cleft number February 1998 and February 2000.
Sl. 4: Število zajed februarja 1998 in februarja 2000.

an increase in the estimated density but a scarcity of full size clams. More increase in density was observed in June, but the commercial fraction was steadily low. No clear pattern was observed in 1999 and the most important fact is the entry of the young-of-the-year, split into two semi-cohorts confirming the results observed by Keller *et al*. (2002). It must be considered, however, only indicative of the presence of specimens under the theoretical gear selectivity, specimens not included in estimated density, computed only for clams from 10 mm onwards. The data from the last survey didn't vary substantially in density and the decrease in average length (Tab. 2) is an effect of the presence of juveniles. The average length calculated for each haul diminished with increasing sea depth, as previously observed in other areas as well (Del Piero *et al.*, 1998) and this fact was attributed to the fishery pressures exerted year after year in the deeper area, being the fishery formally banned from 3 m depth to the coastline during the entire period when the sampling was done. On the other side, the experimental dredge was designed in 1983 by Dr. Froglia from ISMAR (Ancona, Italy) especially for the dominant pure sand substrate of Central Italy, and where the substrate changes suddenly as in the Gulf of Trieste, it may be less efficient as observed in previous studies (D. Del Piero, *pers. observations*). Following that, the clam population at different depths is quite different and only ca 22 % of the frequency distributions tested (16 from 73 paired tests, Tab. 3) belong to the same statistical population ($p < 0.05$) even if the area explored is limited.

The thin sections (177 with distinct marks out of the 180 in total) showed that cleft formation starts in November as in Scaricci (1995-96), but the author (*ibid.*) never observed a cleft in shells less than 9 mm in length, as reported in the present study. The commercial fraction (≥ 25 mm) was overall low in the samples (Tab. 1) and the individuals had 3 or 4 clefts. It must be underlined that the commercial fishery deals with minimum size, but as Keller *et al.* (2002) stressed, there is time to ask if minimum size still has significance. Keller *et al.* (2002) found important differences in age for *Callista chione* sampled in different areas, but the length was the same. There are differences in the growth rate among areas but the minimum size is the same.

Another critical point is the size reduction related to settlement year, estimated from the number of clefts (Fig. 3): for example, the 2000 sample done in February (when the formation process is considered to be concluded, Scaricci (1995-96) showed two clefts in clams between 14 and 16.3 mm in length, then belonging to the cohort (or semi-cohort) settled in 1998, but specimens with two clefts in February 1998 (settled in 1996) have a higher size between 16 and 22.5 mm (Fig. 4). The difference between the two series is significant (Kruskall-Wallis test: 22.42, $p < 0.001$, $n = 34$). In February 1998 three clams between 12 and 16 mm had only one cleft, and are part of the 1997 cohort. So it can be affirmed that the growth of 1997 recruits is comparable to the results of the previous years (Keller *et al.*, 2002) but the cohorts settled after following a different pattern. Recent elaboration of data samples done in 2009 compared to the present data on shell weight/length rate show a significant difference between the series, being 0.58 for this set and 1.03 for the 2009 set (Dwass-Steel-Chritchlow-Fligner test for Pairwise Comparisons $p < 0.000$, Systat 13, G. Valli *pers. comm.*), other comparisons still in progress regarding all the data set collected from 1975 confirm the anomaly of the present set.

CONCLUSIONS

Stock management of *Chamelea gallina* (a species progressively impoverished and with wide variability in growth rate and recruitment) should be addressed only after cohorts are recognized and carefully evaluated.

At the present, it seems there are no conceptual frames satisfying that and the practical application could be very difficult, but for a stock depleted in quantity and demographic structure, this should be the only way to follow. The minimum size only (fixed at 25 mm in 1963 by a national law) without the age estimation obtained from the shell, appears to be unsatisfactory. Valli *et al*. (1985) argued that the average size of fished clams was higher, so a revision is urgent. This is not a suggestion for landing size diminution, but instead, for careful consideration regarding what to do when organisms have a low growth rate, no matter the reason why. Furthermore, the average length was and is higher where the fishery activity is formally banned (2 m depth) but the exploitable area decreased year after year (Del Piero *et al*., 1998; de Flego, 2011) so derogation was conceded to the fleet (with yearly renewal) for the exploitation in the area between 2.5 and 3 m depth. The new rules in force since June 1st, 2010 (Reg. (CE) 1967/2006) fix in 0.3 nm from the coast the minimum distance for exerting that fishery so the more productive areas of the Monfalcone Maritime District are *de facto* excluded. The 2009 and 2011 surveys confirmed the critical status of the clam population in spite of the efforts made by the Consortium to shorten the fishing season and quantities.

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PREGLED RASTIŠČ ŠKOLJK VRSTE *CHAMELEA GALLINA* NA OBMOČJU LIGNANA (TRŽAŠKI ZALIV, JADRANSKO MORJE)

Stefano BIONDI & Donatella DEL PIERO

Department of Life Sciences, University of Trieste, I-34127 Trieste, Via L. Giorgieri 10, Italy
E-mail: delpiero@units.it

POVZETEK

Školjka vrste Chamelea gallina *je v sedimentu živeča školjka, ki uspeva v vseh evropskih obalnih vodah, najpogosteje na peščenem dnu. Že dolgo je izredno pomemben morski vir za italijansko školjkarstvo, zlasti ob zahodni jadranski obali. Školjkarstvo v Tržaškem zalivu, najsevernejšem delu Jadranskega morja, se sooča z velikim upadanjem njenega števila. Po njenem množičnem poginu jeseni 1996 je ni bilo dovoljeno nabirati do januarja 1998, toda ponovno vzrejo njenega zaroda sta otežila zmanjšano rekrutiranje in nizka stopnja rasti, kot so pokazale sezonske raziskave, izvedene na peščenem dnu nasproti Lignana med leti 1997 in 2000. Raziskave so bile narejene vzdolž diagonale s pomočjo ribiške ladje, opremljene s prilagojeno hidravlično vlačilno mrežo, v skladu s protokolom za poskusno gojenje školjke: 50 m vleke, zajemanje vzorcev na vsakem metru globine od 2 do 6 m. Starost školjk smo ocenili na podlagi prereza desne lupine pri dvajsetih primerkih, naključno izbranih iz vzorca, zajetega na globini 4 m. Zajede na tankem predelu 177 (od vsega skupaj 180) primerkov kažejo na razliko med rastnimi vzorci kohorte in počasnejšo rastjo po letu 1997. Kot smo opazili na območju Lignana leto dni pred tem, zajede običajno nastanejo jeseni. Prvič smo jih opazili tudi pri školjkah, manjših od 9 mm, pri čemer so bile nekatere leto dni starejše od drugih podobne velikosti. V času vzorčenja je bila njihova gostota (ind. m^{-2}) majhna. Razen enkratnih visokih vrednosti, izmerjenih leta 2007, se gostota školjk v Tržaškem zalivu ni povečala. Upravljanja staležev morskega vira, kot je* C. gallina*, za katero ni značilno le progresivno zmanjševanje tako gostote kot demografske strukture, marveč tudi izredno raznolika rast in rekrutiranje, se je treba ustrezno lotiti ter našteti kohorte in jih skrbno opazovati. Po drugi strani so se območja, primerna za nabiranje školjk (školjkarstva ni*

mogoče izvajati na globinah, manjših od 3 m), bistveno skrčila v osemdesetih letih 20. stoletja. V Tržaškem zalivu so pred leti zaradi posebnih značilnosti območja določili mejno globino 2,5 m, vendar pa je nova uredba, ki velja od 1. 6. 2010 (Reg. (CE) 1967/2006), za hidravlične vlačilke določila mejno oddaljenost 0,3 NM od obale, zaradi česar se na preostalih školjčiščih v Tržaškem zalivu ne sme nabirati školjk.

Ključne besede: *Chamelea gallina*, Tržaški zaliv, rast, gojenje, upravljanje

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NEW RECORDS OF THE PARROT FISH, *SPARISOMA CRETENSE,* AND THE CLEAVER WRASSE, *XYRICHTYS NOVACULA,* BY VISUAL CENSUS IN THE SOUTHERN ADRIATIC

Claudia KRUSCHEL, Ivana ZUBAK & Stewart T. SCHULTZ
University of Zadar, Department of Maritime Sciences, HR-23000 Zadar, M. Pavlinovića bb, Croatia
E-mail: ckrusche@unizd.hr

Sven DAHLKE
University of Greifswald, Biologische Station Hiddensee, 18565 Kloster / Hiddensee Biologenweg 15, Germany

ABSTRACT

In this publication, we will report on new records for two fish species Sparisoma cretense *and* Xyrichtys novacula *in the Southern Adriatic Sea (Croatia), found in August 2011. Both species are potential indicators for tropicalization. All specimens were visually detected and identified over the course of a long term fish survey (dating back to 2009) involving a lure assisted visual census.* S. cretense *has been observed at locations in the Molunat and Cavtat areas while the* X. novacula *specimens have been observed at a SE location at Korčula Island. The 2009-2011 survey has so far covered a total of 100 sites representing a broad geographical range from the southernmost locations of the Croatian Adriatic (Prevlaka) to northern locations in the Gulf of Trieste and from the main coast of Croatia to islands as distant from the main shore as Lastovo Island.*

Key words: tropicalization, lure assisted visual census, Adriatic, *Sparisoma cretense*, *Xyrichtys novacula*

NUOVI AVVISTAMENTI DI PESCE PAPPAGALLO, *SPARISOMA CRETENSE,* E DI PESCE PETTINE, *XYRICHTYS NOVACULA,* COL CENSIMENTO VISIVO IN ADRIATICO MERIDIONALE

SINTESI

L'articolo riporta nuove segnalazioni di due specie ittiche, Sparisoma cretense *e* Xyrichtys novacula*, in acque croate dell'Adriatico meridionale, nell'agosto del 2011. Entrambe le specie sono potenziali indicatori di tropicalizzazione. Tutti gli individui sono stati osservati e identificati durante una lunga indagine della fauna ittica (avviata nel 2009), con il metodo del censimento visivo con l'ausilio di esche. Esemplari di* S. cretense *sono stati osservati in prossimità di Molonta (Molunat) e Ragusavecchia (Cavtat), mentre individui di* X. novacula *sono stati avvistati nella parte sud-orientale dell'isola di Curzola (Korčula). Negli anni 2009-2011, la ricerca ha compreso 100 siti di campionamento, coprendo un'ampia distanza geografica che va dalle località più meridionali dell'Adriatico croato (Vittaglina o Prevlaka) alle località più settentrionali nel Golfo di Trieste, nonché dalla linea di costa alle isole che distano dalla terraferma al pari dell'isola di Lagosta (Lastovo).*

Parole chiave: tropicalizzazione, censimento visivo con l'ausilio di esche, Adriatico, *Sparisoma cretense*, *Xyrichtys novacula*

INTRODUCTION

The marine biodiversity of the Mediterranean is undergoing changes which can be described as a process towards tropicalization, the increased occurrence of warm-water biota (Bianchi & Morri, 2003). This process has two major components, the introduction of exotic species novel to the Mediterranean, and the northward spread of Mediterranean native species with subtropical affinities which were, until recently, confined to the southern parts of the basin (Bianchi & Morri, 1993, 1994, 2004). The occurrence and spread of thermophilic species in the Mediterranean Sea results from four distinct processes: Atlantic influx, lessepsian migration, introductions by humans, and present-day sea warming. While the first three facilitate the physical occurrence of warm water fish outside their usual range, the fourth constitutes the conditions under which the northward spread of such fish species is possible. Sea warming has been, despite large cyclic fluctuations, a positive trend in the Mediterranean since the mid 1980s (Bianchi & Morri, 1994; Astraldi *et al.*, 1995; Vacchi *et* al., 2001; Bianchi, 2007).

Most indications for the northward spread of thermophilic species come from chance observations. To test the hypothesis on the occurrence of biogeographical expansions and on the establishment of a new population, more targeted field work is needed. Here, we report on results from a survey designed to investigate and monitor demersal fish community structure and fish-habitat associations in the eastern Adriatic (Croatia). This long term survey assures accurate revisits of fixed sites spread over a large geographical range. While not primarily established for the study of northward spreading species, this method does give the opportunity to systematically investigate the geographical distribution of individual species, the changes thereof and in addition, their associations with habitats and other fish species as well as various aspects of fish behaviour.

One possibly northward spreading species once restricted to the warmer eastern Mediterranean but now crossing temperature divides is the parrotfish, *Sparisoma cretense* (Linnaeus, 1758) (Bianchi, 2007; Abecasis *et al.*, 2008). It is a reef-associated omnivorous fish occurring in the Eastern Atlantic: Portugal, Azores and Madeira south to the Canary Islands and Senegal. While still more common along the eastern and southern Mediterranean coasts, it has also been found in the Tyrrhenian Sea since the summer of 1991 (Bianchi & Morri, 1994), the southern Italian Adriatic (Reiner, 1996; Guidetti & Boero, 2001, 2002), and the Croatian part of the Adriatic. Two specimens caught in 1925 near Komiža, Vis Island, are kept in the Ichthyological collection of the Institute of Oceanography and Fisheries in Split (Pallaoro & Jardas, 1996) while more recent observations were reported by Mušin (1989) in the Dubrovnik area and Dulčić & Pallaoro (2001) near the Vrhovnjaci archipelago near the Lastovo Island as well as in the Palagruža archipelago.

Another potentially northward spreading species is the cleaver wrasse (or pearly razorfish), *Xyrichtys novacula* (Linneus, 1758), an invertebrate feeder native to the Western Atlantic: North Carolina, the USA, the northern Gulf of Mexico, and the Caribbean to Brazil, but also present in the Eastern Atlantic: the southern coast of Spain to south of Cape Lopez, Gabon, Azores, Madeira, the Canary Islands, Cape Verde and Sao Tome Island, as well as in the Western and Central Mediterranean (Tortonese, 1975; Robins & Ray, 1986; Cardinale *et al.*,1997; Candi *et al.*, 2004). A specimen caught in 1932 at Korčula Island, Croatia, is kept in the Croatian Natural History Museum in Zagreb and Šoljan (1975) reported repeated records of this species from the Adriatic Sea. Onofri (1982, 1987) reported and studied *X. novacula* from a SE location on Korčula Island, Croatia. A single specimen, caught in 1988 near Lumbarda, Korčula Island, is kept in the Ichthyological collection of the Institute of Oceanography and Fisheries in Split (Pallaoro & Jardas, 1996), while the only later sighting for the Croatian Adriatic recorded in the literature was in Jelsa, Hvar island and dates back to 2000 (Dulčić & Pallaoro, 2001).

MATERIALS AND METHODS

Our observations were made during a fish survey in August 2011, targeting a total of 28 locations during which the lure assisted visual census method was used. This method was described in detail and validated in Schultz & Kruschel (2010), Kruschel & Schultz (2010), and Kruschel & Schultz (2012). This was the latest of a series of surveys since 2009 increasing the total number of sites to 100 (Fig. 1), approximately half of which are revisited every year, and a third of which are visited twice every year.

At each visited location, a total observation time ranging from 45-90 minutes per site was applied. Fish were observed along 50-100 logistically identical snorkel transects as well as outside such transects, and also by a second observer not involved in transect-based visual census loosely following the first. The depth range covered was 0–20 m, with maximum depth depending on water transparency and steepness of the bottom profile. The lead snorkeler swam at the surface holding the lure line. The lure consisted of a piece of double conical lead (3 x 0.5 cm) attached to a monofilament fishing line wrapped around a Styrofoam board. At random intervals, the lure was lowered to within approximately 5 cm of the substrate's surface and moved at approximately 0.3 m s^{-1} for 10 seconds (approximately 3 m distance). The snorkeler observed and identified all fish 1 m to both sides of the lure line's path and in the entire water column up to the surface.

Habitat characteristics along the entire transect were quantified and recorded as well. In between lure pre-

sentations, the snorkeler moved randomly to determine the starting point for the next lure presentation. Fish observed during such in-between-transect periods were recorded along with their habitat occupancy at the time of observation if they constituted a species not yet encountered at the actual site or a species of special interest.

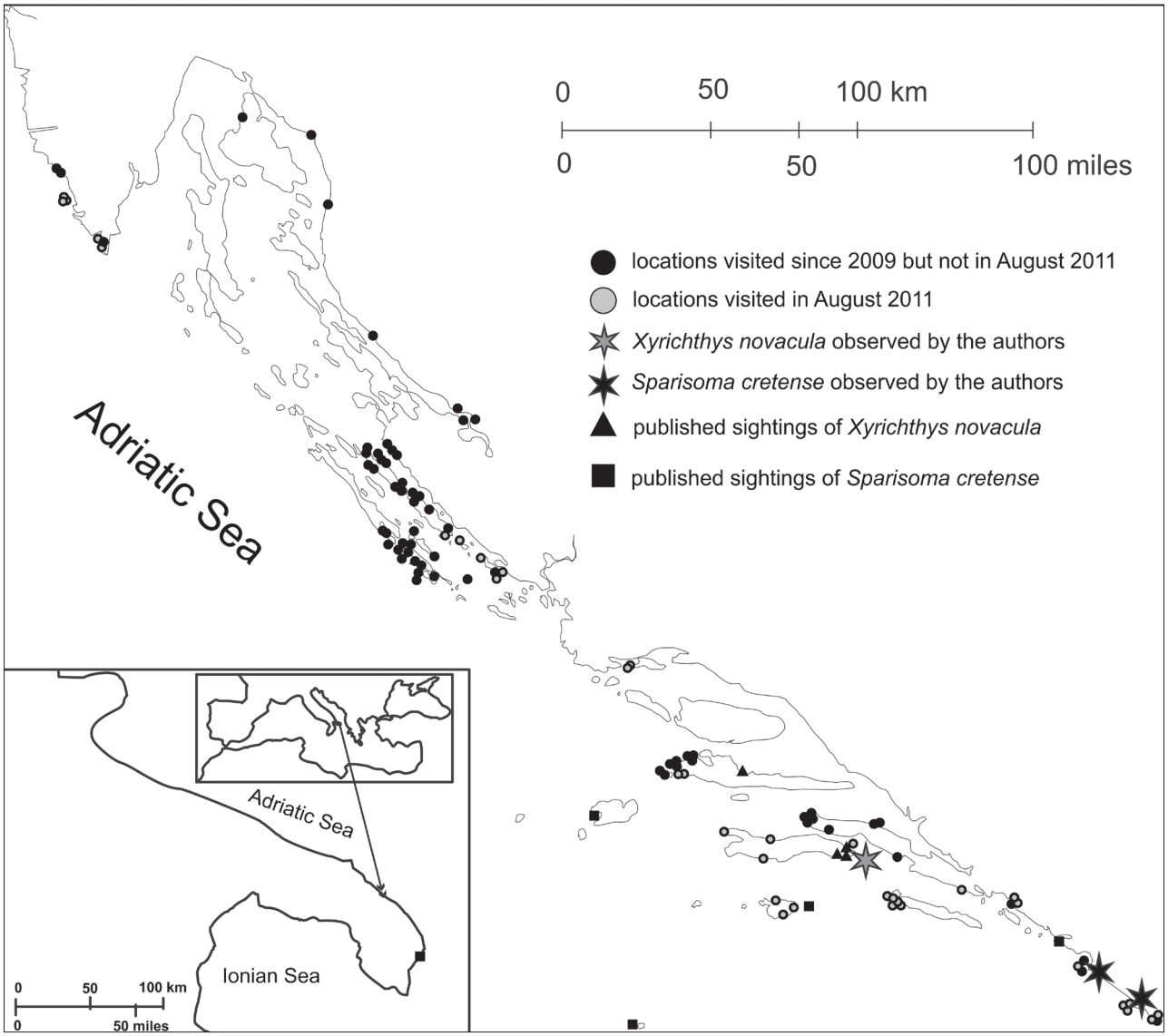

Fig. 1: Map locations representing the total of 100 sites visited since 2009 and sites representing published sightings of *Sparisoma cretense* ***(full squares) and*** *Xyrichtys novacula* ***(full triangles), including those from the southwestern Adriatic (Italy) as indicated in the additional map in the lower left. Grey circles indicate locations representing the 28 eastern Adriatic (Croatia) sites visited in August 2011 (many for the first time), full black circles indicate locations representing sites that had been visited once or multiple times since 2009 but not in August 2011. Black stars indicate August 2011 site-locations at which*** *S. cretense* ***have been sighted, grey star indicates August 2011 site-locations of*** *X. novacula***.***

Sl. 1: Zemljevid, ki prikazuje 100 lokacij, ki smo jih začeli obiskovati leta 2009, ter lokacije, kjer je so doslej zabeležili vrsti *Sparisoma cretense* ***(črni kvadrat) in*** *Xyrichtys novacula* ***(črni trikotnik), vključno z lokacijami v jugozahodnem Jadranu (Italija), kot je prikazano na pomanjšanem zemljevidu v spodnjem levem kotu. S sivimi krogi je označenih 20 lokacij v vzhodnem Jadranu (Hrvaška), ki smo jih obiskali avgusta 2011 (mnoge prvič); s črnimi krogi so označene lokacije, ki smo jih od leta 2009 naprej obiskali enkrat ali večkrat, vendar ne v avgustu 2011. S črno zvezdico so označene lokacije, na katerih smo avgusta 2011 opazili vrsto*** *S. cretense*, ***s sivo zvezdico pa lokacije, na kateri smo avgusta 2011 opazili vrsto*** *X. novacula***.***

In addition, a second snorkeler, acting as photographer, followed behind the lure-presenting snorkeler to photographically record habitat types and to generate evidence for species of special interest.

RESULTS

Sparisoma cretense

One specimen of *S. cretense* in grayish terminal phase coloration and approximately 15 cm long was encountered on August 17, 2011, at 17:00, by the photographer (S. Dahlke) in an embayment near the town of Cavtat (Tab. 1). The specimen was alone and was, for the duration of the 7 minute observation, swimming very actively back and forth across a group of smaller boulders neighboring the upper edge of a *Posidonia oceanica* meadow, often picking food (apparently epiphytes) from the rocky surface but not from the nearby seagrass blades.

The other specimen of *S. cretense*, also terminal phase, and also approximately 15 cm long, was encountered by the lure-trolling diver (C. Kruschel) on August 18, 2011, at 15:00, between two lure presentations within the north-west facing embayment near the village of Molunat (Tab.1). The specimen was alone at a depth of approximately 6 m and was observed remaining, for the duration of the 5 minute observation, at one boulder located within a patch of *P. oceanica* where it was picking food off the rocky surface and off the neighbouring seagrass blades.

Xyrichtys novacula

Two specimens, the sex of which were not determined, approximately 15 cm long, were encountered by the lure-trolling snorkeler (C. Kruschel) on August 23, 2011, 14:00 while presenting the lure at a depth of 3 m over a patch of unconsolidated sand in between the upper edge of a sparse *Cymodocea nodosa* bed and the lower edge of a boulder-fringing *P. oceanica* patch in an outer coast embayment near the village of Lumbarda, in the SE of Korčula Island (Tab. 1). The specimens remained, for the 5 min observation, spatially close to each other (less than 50 cm apart) and both interacted with the lure by following it while it was still presented along the lure transect and later by repeatedly visiting it for visual inspection, while it was resting on the ground as the snorkeler spent additional observation time following the completion of the transect. Both specimens were pale pinkish with darker sprinkles spread over their dorsal area giving the impression of a pearlescent sheen. The specimens were not observed feeding; they did, however, frequently assume a vertical, head-down position with the head within a few centimetres from the bottom. Neither specimen showed any attraction or adverse reaction to the snorkeler who remained on the surface.

Within the same location but ca. 300 m from the place described above, another specimen, the sex of which was not determined and which was approximately 15 cm in length, was encountered by the photographer (S. Dahlke) at a depth of 3 m on August 18, 2011, at 14:30, within a patch of unconsolidated sand not immediately neighbouring any structured habitat. In response to the observer diving down closer to the specimen in order to obtain photographs, it took notice of the approach and quickly buried itself into the sand thereby preventing any subsequent imaging.

DISCUSSION

The parrotfish, *S. cretense,* inhabits rocky reefs and sea grass beds in shallow waters to a depth of about 50 m and is, aside from some very sporadic records around the basin (Bini, 1968; Tortonese, 1975; Parenzan, 1983; Bianchi & Morri, 1994; Otero & Galeote, 1996 and references therein; Guidetti & Boero, 2001, 2002), established along the Mediterranean southern and eastern coasts (*e.g.,* North Africa, Sicily and the Aegean Sea) (Tortonese,1975; Bernardi *et al.,* 2000). This distribution suggests that *S. cretense* is one of the Mediterranean thermophilic southern species. Guidetti & Boero (2001, 2002) studied this species in SE Apulia, south-western Adriatic (Fig. 1), and concluded that while the species is relatively rare there, it could constitute an established and stable population outside its typical distribution. This may support the hypothesis that *S. cretense*

Tab. 1: GPS position (decimal degrees), depth, and number of individuals of *Sparisoma cretense* ***(S) and*** *Xyrichtys novacula* ***(X).***
Tab. 1: Položaj GPS (decimalni zapis), globina in število primerkov vrst *Sparisoma cretense* ***(S) in*** *Xyrichtys novacula* ***(X).***

Location name	Latitude (N)	Longitude (E)	Depth (m)	Species	Number of individuals
Cavtat	42.58282	18.209492	3	S	1
Molunat	42.456138	18.426035	6	S	1
Lumbarda 1	42.914470	17.186978	3	X	2
Lumbarda 2	42.916673	17.184583	3	X	1

is expanding northwards in response to climate change driven warming of Mediterranean waters. In the eastern Adriatic, two specimens caught in 1925 in Komiža and kept in the Ichthyological collection of the Institute of Oceanography and Fisheries in Split represent the most northward record published so far. From 2000 to date, the most recent published reports of *S. cretense* from the eastern Adriatic (Dulčić & Pallaoro, 2001) where one specimen was caught near the Vrhovnjaci archipelago (42.763 N, 17.115 E) and two more specimens were recorded by visual census in the Palagruža archipelago (42.385 N, 16.254 E) in September 2000. The first location is further north than the sightings reported here (Cavtat and Molunat, Tab. 1) while the latter is further south. Another record of *S. cretense* in the Dubrovnik area (Mušin, 1989) represents a location approximately at the same latitude as the sightings reported here. Therefore our encounters with *S. cretense* do not seem to indicate a more northward distribution of this species now as compared to 10, 20 or even 85 years ago. Also, sightings from this survey represent exclusively main coast locations, while the published locations include the Palagruža Islands which constitute a mid Adriatic location and the Vis and Vrhovnjaci Islands which are off the main coast locations. Both are more exposed and also more western than any sites visited during this survey and may therefore be more likely to be encountered by *S. cretense* provided the source population was the nearest known established population in the south-western Adriatic (Guidetti & Boero, 2001). Considering that we have not detected *S. cretense* during any of the earlier, previous fish surveys (spanning the entire Croatian coast) which we have regularly conducted since 2009 (twice a year in spring and summer/fall) may suggest that this species remains very rare in the Croatian Adriatic and may not have established stable populations, a hypothesis that can only be tested by additional research. One reason for the lack of encounter via our survey method may be that in locations with low water transparency, we are limited to depths less than 10 m. The 0-10 m depth range does not, according to Guidetti & Boero (2001, 2002), represent the preferred depth range of adult *S. cretense* which was determined in their study as being between 12-15 m. A depth range of 0-10 m is, however, suitable for encountering juveniles which would be plausible indicators of establishing populations and which were recorded by Guidetti & Boero (2001) exclusively between 5 and 15 m.

Published information on the cleaver wrasse, *X. novacula,* in the Mediterranean comes primarily from the Tyrrhenian Sea, where the species inhabits sandy bays and prefers well-sorted fine bottoms over rocky and vegetated (*P. oceanica*) grounds (Cardinale *et al.,* 1997). There the species is heavily exploited, primarily via trawl netting. As it prefers shallower waters in the summer but retreats deeper when the surface waters cool, lower winter catches result (Candi *et al.,* 2004). Considering the frequency with which the coastal sediments in the eastern Adriatic (down to 80 m) are trawled, one would expect regular and more frequent fisheries related sightings of this species provided it was indeed undergoing a northward expansion by establishing stable populations. In contrast, the species has been only sporadically reported from the eastern Adriatic, with reports, however, dating as far back as 1932. The most recent published report of *X. novacula* along the eastern Adriatic comes from a location near Jelsa (Hvar Island, 43.17 N, 16.69 E) and remains, to the best of our knowledge, the northernmost record of this particular species in the Adriatic Sea (Dulčić & Pallaoro, 2001). It is surprising that only now, in 2011, we encountered this species for the first time considering that we have been surveying the shallow water (0-20 m) benthos at 100 locations, including sandy bays, along the entire Croatian Coast since 2009, with one third of these sites visited twice a year. The only location at which we did detect the species (Korčula Island, Tab. 1) is more southern than the most recent previous reported locations (Dulčić & Pallaoro, 2001) and roughly identical with those reported by Onofri (1982, 1987) and with the location at which a specimen kept in the Ichthyological collection of the Institute of Oceanography and Fisheries in Split, was caught in 1988 and also with the location of the specimen kept in the Croatian Natural History Museum, Zagreb caught in 1932. Therefore we are reluctant to interpret our sightings of *X. novacula* as an indication of an ongoing northward spread of the species. Our sightings, however, may indicate the possibility that SE Korčula Island is occupied by a small established population, a hypothesis that can be tested only by additional research.

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NOVI ZAPISI O POJAVLJANJU PAPAGAJKE, *SPARISOMA CRETENSE* IN VRSTE *XYRICHTYS NOVACULA*, NASTALI NA PODLAGI VIZUALNEGA POPISA V JUŽNEM JADRANU

Claudia KRUSCHEL, Ivana ZUBAK & Stewart T. SCHULTZ
University of Zadar, Department of Maritime Sciences, HR-23000 Zadar, M. Pavlinovića bb, Croatia
E-mail: ckrusche@unizd.hr

Sven DAHLKE
University of Greifswald, Biologische Station Hiddensee, 18565 Kloster / Hiddensee Biologenweg 15, Germany

POVZETEK

V članku poročamo o novih zapisih o pojavljanju dveh ribjih vrst in sicer papagajke, Sparisoma cretense *in* Xyrichtys novacula*, na jugu hrvaškega dela Jadranskega morja avgusta 2011. Obe vrsti sta potencialna indikatorja tropikalizacije. Vse primerke smo vizualno opazili in identificirali v sklopu daljšega preučevanja ribjih vrst (začelo se je leta 2009), ki je vključevalo vizualni popis s pomočjo vabe. Vrsto* S. cretense *smo opazili na več lokacijah na območju Molunata in Cavtata, primerke vrste* X. novacula *pa na lokaciji jugovzhodno od Korčule. V raziskavo, ki je potekala med letoma 2009 in 2011, smo skupno vključili 100 lokacij v širokem geografskem obsegu. Raztezajo se vse od najjužnejših predelov hrvaškega Jadrana (Prevlaka) do severnih lokacij v Tržaškem zalivu ter od hrvaške obale pa do najbolj oddaljenih otokov, kot je Lastovo.*

Ključne besede: tropikalizacija, vizualni popis s pomočjo vabe, Jadran, *Sparisoma cretense*, *Xyrichtys novacula*

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ADDITIONAL RECORDS OF LESSEPSIAN TELEOST SPECIES OFF THE TUNISIAN COAST (CENTRAL MEDITERRANEAN)

Sihem RAFRAFI-NOUIRA & Moncef BOUMAÏZA
Laboratoire d'Hydrobiologie Littorale et Limnique, Université du 07 novembre à Carthage, Faculté des Sciences, Zarzouna, 7021 Bizerte, Tunisia

Christian REYNAUD & Christian CAPAPÉ
Laboratoire interdisciplinaire de Recherche sur la Didactique, l'Éducation et la Formation, E. A. 3749, case 77, Université Montpellier II, Sciences et Techniques du Languedoc, 34095 Montpellier cedex 5, France
E-mail: capape@univ-montp2.fr

ABSTRACT

Investigations conducted off the northern Tunisian coast (central Mediterranean) allowed for the collection of specimens of three Lessepsian teleost migrants: the black-barred halfbeak Hemiramphus far *(Forsskål, 1775), dusky spinefoot* Siganus luridus *(Rüppell, 1829) and marbled spinefoot* Siganus rivulatus *Forsskål, 1775. The species are described in this paper including morphometric measurements and meristic counts. These findings constitute the northernmost extension range for these species in the region, and their westernmost extension range in the Mediterranean Sea.*

Key words: Osteichthyes, Hemiramphidae, Siganidae, Lessepsian migrant, Tunisian coast, Mediterranean

NUOVI AVVISTAMENTI DI TELEOSTEI LESSEPSIANI AL LARGO DELLA COSTA DELLA TUNISIA (MEDITERRANEO CENTRALE)

SINTESI

Ricerche condotte nelle acque al largo della costa settentrionale della Tunisia (Mediterraneo centrale) hanno permesso di raccogliere esemplari di tre specie di teleostei migranti lessepsiani: pesce mezzobecco Hemiramphus far *(Forsskål, 1775), pesce coniglio* Siganus luridus *(Rüppell, 1829) e siganide marmorizzato* Siganus rivulatus *Forsskål, 1775. Gli autori forniscono la descrizione delle specie, completa di misurazioni morfometriche e conte meristiche. Tali ritrovamenti rappresentano la segnalazione più settentrionale delle specie nella regione, e l'avvistamento più occidentale nel mare Mediterraneo.*

Parole chiave: Osteichthyes, Hemiramphidae, Siganidae, migranti lessepsiani, costa della Tunisia, mare Mediterraneo

INTRODUCTION

Observations carried out over the last decades have shown the successful introductions of alien species, mainly as the result of the increasing temperature of the Mediterranean Sea (Francour *et al*., 1994). These introductions induce competition between alien and native species, and consequently a strong modification of local biodiversity particularly affecting fish species (Ben Raïs Lasram & Mouillot, 2009).

Investigations conducted off the northern Tunisian coast from 2006 to 2012 resulted in the capture of 3 alien teleost species previously considered rare or unknown in the area: black-barred halfbeak *Hemiramphus far* (Forsskål, 1775), dusky spinefoot *Siganus luridus* (Rüppell, 1829) and marbled spinefoot *Siganus rivulatus* Forsskål, 1775. These captures suggest an extension range of these species in the area but also in the Mediterranean Sea (Fig. 1). In this paper we give a short description of the 3 species and comment on both their local and Mediterranean distributions.

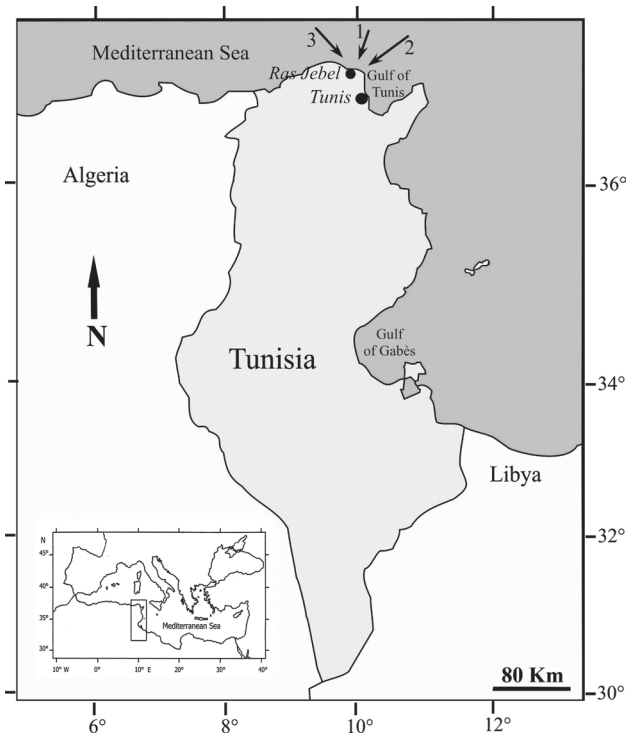

Fig. 1: Map of the Mediterranean showing Tunisia and map of the coast of Tunisia with arrows pointing out the capture site of: 1) Black-barred halfbeak *Hemiramphus far* ***(Forsskål, 1775); 2) Dusky spinefoot*** *Siganus luridus* ***(Rüppell, 1829); 3) Marbled spinefoot*** *Siganus rivulatus* ***Forsskål, 1775.***

Sl. 1: Zemljevid Sredozemlja s Tunizijo in zemljevid tunizijske obale s puščicami, usmerjenimi proti lokacijam ulova: 1) vrste *Hemiramphus far* ***(Forsskål, 1775); 2) temnega morskega kunca*** *Siganus luridus* ***(Rüppell, 1829); 3) morskega kunca vrste*** *Siganus rivulatus* ***Forsskål, 1775.***

MATERIAL AND METHODS

All specimens were identified following identification keys and field guides such as Whitehead et al. (1984-1986) and Golani *et al*. (2002), then photographed, measured to the nearest millimetre and weighed for total mass, whereas liver and gonads were weighed to the nearest decigram. Stomach contents were removed and identified to the lowest possible taxon.

RESULTS AND DISCUSSION

Black-barred halfbeak *Hemiramphus far* (Forsskål, 1775)

Hemiramphus far is widely distributed in the Indo-Pacific and east Africa to the Philippines and Samoa (Collette & Parin 1986; Golani *et al*., 2002). The species is rather abundant in the Red Sea and entered the Mediterranean Sea through the Suez Canal where it was first recorded in Palestine as *H. marginatus* by Steinitz (1927). Further records were from Syria (Gruvel, 1929), Rhodes (Tortonese, 1937), Albania (see Collette & Parin, 1986), Egypt (El-Sayed, 1994), Libya (Shakman & Kinzelbach, 2007) and the Aegean Sea, off the coast of Turkey (Akça & Bilecenoglu, 2010)

H. far was reported for the first time in Tunisian waters by Charfi-Cheikhrouha (2004) off Raf-Raf, a city located in the northern region of the Gulf of Tunis. The second recording of this species is described in this paper (Fig. 2A). The specimen was captured on 1st December, 2010, with a gill-net having a mesh size of 24 mm at a depth of 3-4 m, together with labrid and sparid species on a rocky coralligenous bottom partially covered with algae and sea grass. The capture occurred off Ras Jebel, a city very close to Raf-Raf, approximately 5 km north, located at 37°14′34.56″ N and 10°07′48.20″ E.

The specimen was identified as follows: body elongated and laterally compressed, oval in cross-section. Upper jaw short, triangular and naked, without scales. Lower jaw greatly prolongated, beak-like. Dorsal and anal fins posterior in position. Anal fin below middle of dorsal fin lobe. Pectoral fin short. Pre-orbital ridge absent. Caudal fin deeply forked, lower lobe larger than upper lobe. Back grey bluish, with a series of six hardly visible black spots. Belly silvery white. Upper caudal fin yellow. The specimen was preserved in 10 % buffered formaline and deposited in the Ichthyological Collection of the Faculté des Sciences de Bizerte, with the catalogue number FSB-Hem-far-01.

Morphological description, colour, morphometric measurements with percentages of standard length (% SL) and meristic counts (Tab. 1) are in agreement with Collette & Parin (1986), Golani *et al*. (2002) and Akça &

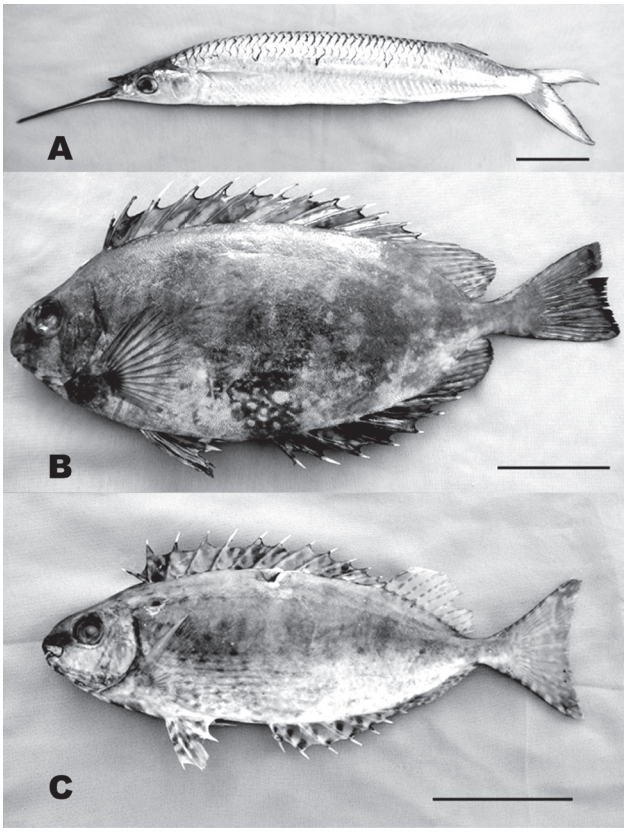

Fig. 2: A) Black-barred halfbeak *H. far*, ***scale bar = 20mm; B) Dusky spinefoot*** *S. luridus*, ***scale bar = 30mm; C) Marbled spinefoot*** *S. rivulatus*, ***scale bar = 50mm.***
Sl. 2: A) vrsta *H. far*, ***merilna enota = 20 mm. B) temni morski kunec*** *S. luridus*, ***merilna enota = 30 mm; C) morski kunec vrste*** *S. rivulatus*, ***merilna enota = 50 mm.***

Bilecenoglu (2010). The gut of the specimen contained undeterminable remains of food. The ovary was externally granulous and contained pre-vitellogenic oocytes. This female was probably a pre-spawning specimen.

Dusky spinefoot *Siganus luridus* (Rüppell, 1829)

Siganus luridus is widely distributed off the eastern African coast, off Réunion Island and in the Arabian Gulf (see Golani *et al*., 2002). The species has been entering the Mediterranean Sea through the Suez Canal since 1955 (Ben-Tuvia, 1964) and is at present successfully established in the eastern Mediterranean Basin; its reproductive biology, food and feeding habits have been studied (Bariche et al., 2003; Bariche, 2006). *S. luridus* migrated westward and is known to date in the Adriatic (Poloniato *et al*., 2010), central Mediterranean (Azzurro & Andaloro, 2004) and southern Mediterranean (Shakman & Kinzelbach, 2007).

S. luridus was first recorded in Tunisian waters by Ktari-Chakroun & Bouhlal (1971), in the Gulf of Tunis (northern Tunisia) and southward in the Gulf of Gabès by Ktari & Ktari (1974). Additionally, Charfi-Cheikhrouha (2004) recorded a specimen captured off Raf-Raf, in 2002. The specimen described in this paper (Fig. 2B), was captured on 27th November, 2010, with a gill-net having a mesh size of 30 mm, at a depth of 5-6 m, on a rocky coralligenous bottom entirely covered with algae, together with several specimens of salema *Sarpa salpa* (Linnaeus 1758). The capture occurred off Ras Jebel, located at 37°13′05.46″ N and 10°11′26.52″ E (Fig. 1).

The specimen was identified as follows: body deep, ellipsoid, compressed. Dorsal fin origin above pectoral fin base. Caudal fin truncated. Head slightly truncate with blunt snout. Mouth small with distinct lips. Longest dorsal spine longer than distance from the front of the eye to posterior edge of the opercle. Small scales embedded in skin. Colour brown to olive green with a touch of yellow on fins. The specimen was preserved in 10% buffered formaline and deposited in the Ichthyological Collection of the Faculté des Sciences de Bizerte, with the catalogue number FSB-Sig-lur-01.

Morphological description, colour, morphometric measurements and meristic counts (Tab. 1) are in agreement with Ben-Tuvia (1986), Golani *et al*. (2002) and Akça & Bilecenoglu (2010).The gut contained unidentified algae, confirming that *S. luridus* is an herbivore species (Barriche, 2006), the concomitant capture of several salemas, other herbivore species, suggests that they occupy the same ecological niche, so an interspecific competition pressure for food between both species cannot be totally excluded. The ovary was inconspicuous and surrounded by thick adipose tissue, the specimen was probably an adult female, size at first maturing occurring between 120 and 160 mm total length following Bariche *et al*. (2003).

Marbled spinefoot *Siganus rivulatus* Forsskål, 1775

The species is known in the Gulf of Aden and the Red Sea (Golani *et al*., 2002) and entered from the latter through the Suez Canal into the Mediterranean Sea where it was first recorded by Steinitz (1927) and at present it is successfully established especially in the eastern basin and the Aegean Sea (Bilecenoglu & Kaya, 2002). Additionally, the species acquired high economic importance in these areas (Papaconstantinou, 1990). The species is also known in the central and southern Mediterranean (Tortonese, 1978; Shakman & Kinzelbach, 2007).

S. rivulatus was observed for the first time by Ktari & Ktari (1974), and probably caught in the Gulf of Gabès (Bradaï *et al*., 2004). Further, two other captures were reported in the same area between May 1995 and October 2001 (Bradaï *et al*., 2004). The specimen presented in this paper was speared by a diver (Fig. 2C), on 30th March, 2011, at a depth of 5-6 m, on a rocky coralligenous bottom entirely covered with algae; it was surrounded by several specimens of salema and common two-banded sea bream *Diplodus vulgaris* (E. Geoffroy

Tab. 1: Morphometric measurements in mm and as % standard length (SL), meristic counts and masses recorded in black-barred halfbeak** H. far **(FSB-Him-far-01), dusky spinefoot** S. luridus **(FSB-Sig-lur-01) and marbled spinefoot** S. rivulatus **(FSB-Sig-riv-01).

Tab. 1: Morfometrične meritve v mm in v % glede na standardno dolžino (SL), meristična štetja in teža, izmerjeni pri vrsti** H. far **(FSB-Him-far-01), temnem morskem kuncu** S. luridus **(FSB-Sig-lur-01) in morskem kuncu vrste** S. rivulatus **(FSB-Sig-riv-01).

Characteristic	**FSB-Him-far-01**		**FSB-Sig-lur-01**		**FSB-Sig-riv-01**	
Sex	Pre-spawning female		Adult female		Pre-spawning female	
Morphometric measurements	mm	% SL	mm	% SL	mm	% SL
Total length	365	115.8	203	118.02	193	119.1
Standard length	315	100	172	100	162	100
Fork length	329	104.4	200	116.2	181	111.7
Pre-dorsal fin length	254	80.6	34	19.7	38.4	23.7
Pre-pectoral fin length	122.9	39.01	36.5	21.2	35.3	21.7
Pre-anal fin length	268	85.07	87	50.5	80.4	49.6
Longitudinal eye diameter	13.5	4.2	11.5	6.6	11.1	6.8
Vertical eye diameter	13.5	4.2	11.5	6.6	9	5.5
Dorsal fin length	31.7	10.06	119.4	69.4	111	68.5
Pectoral fin length	11.4	3.6	12.1	7.03	9.4	5.8
Anal fin length	19.2	6.09	72.6	42.2	68.4	42.2
Pelvic fin length	5.3	1.6	4.6	2.67	6.2	3.8
Caudal fin length	17.1	5.4	16.6	9.6	13.2	8.1
Body height	28.4	9.01	24.1	14.01	17	10.4
Pre-orbitary length	82.6	26.2	13.5	7.8	14.1	8.7
Post-orbitary length	23.7	7.5	12.7	7.3	14	8.6
Head length	118.7	37.6	37	21.5	38	23.4
Inter-orbitary length	15.2	4.8	12	6.9	11.7	7.2
Upper jaw	12.2	3.8	-	-	-	-
Lower jaw	74.1	23.5	-	-	-	-
Meristic counts						
Dorsal fin rays	12		XIV + 11		XIV + 10	
Pectoral fin rays	13		16		15	
Anal fin rays	11		VII + 10		VII + 9	
Caudal fin rays	24		19		18	
Pelvic fin rays	6		II + 3		II + 3	
Weight (dg)						
Total body	143.2		129.1		64.9	
Eviscerated body	137.9		110.8			55.4
Liver	1.8		1			0.8
Gonad	0.4		0.1			0.1
Stomach content	1.3		5.9			0.9

Saint-Hilaire, 1817). The capture occurred off Ras Jebel, located at 37°15′48.53″ N and 10°04′27.65″ E (Fig. 1).

The specimen was identified as follows: body oval and compressed caudal fin forked. Head moderately concave with blunt snout. Mouth small with distinct lips, the upper thicker and slightly overhanging. Longest dorsal spine shorter than distance from front of the eye to the posterior edge of the opercle. Small embedded

scales. Colour of body grey-green to brown, with yellow-gold lines on flanks. Belly light-brown to yellow. The specimen is preserved in 10% buffered formaline and deposited in the Ichthyological Collection of the Faculté des Sciences de Bizerte, with the catalogue number FSB-Sig-riv-01.

Morphological description, colour, morphometric measurements and meristic counts (Tab. 1) are in agreement with Ben-Tuvia (1986), Golani *et al*. (2002) and Dulčić & Pallaoro (2004). The gut contained unidentified algae, confirming that like *S. luridus*, *S. rivulatus* is an herbivore species, Barriche (2006) noted that an interspecific competition pressure for food between both species cannot be totally excluded. The ovary was externally granulous and contained pre-vitellogenic oocytes. This female was probably a pre-spawning specimen.

Lessepsian migrations off the Tunisian coast

The recent captures of *H. far*, *S. luridus* and *S. rivulatus* confirm that these Lessepsian species could be successfully established in the new area, at least for the both siganid species, already recorded four decades ago. However, the occurrence of *H. far* is rather recent locally, and two records are not sufficient to definitively state that the population is established, such as is the case for other Mediterranean regions (Golani *et al*., 2002). The records of the three species off Ras Jebel constitute their northernmost extension range off the Tunisian coast, and their westernmost extension range in the Mediterranean Sea. Additionally, these few records from the northern Tunisian coast were probably due to the fact that the area is characterized by relatively colder and less saline waters (Lubet & Azzouz, 1969), than in southern areas such as the Gulf of Gabès (Ben Othman, 1971).

The Tunisian coast is located in the central Mediterranean, constituting a transitional area between the western and eastern basins; Bradaï *et al*. (2004) reported the occurrence of 14 alien species in the Tunisian waters, 8 from the Red Sea and 6 from the eastern Atlantic. Additionally, 9 other alien species were further recorded in the area (Ben Souissi *et al*., 2005a, b, 2006a, b, 2011a, b; Ben Amor *et al*., 2008, Azzouz *et al*., 2011; Mansour *et al*., 2011). At present, 4 allochtonous species are successfully established in Tunisian waters, an Atlantic migrant, blunthead puffer *Sphoeroides pachygaster* (Müller & Troschel, 1848) (Chérif *et al*., 2010), and 3 lessepsian migrants Por's goatfish *Upeneus pori* Ben-Tuvia & Golani, 1989 (Ben Souissi *et al*., 2005a; Azzouz *et al*., 2010), filefish *Stephanolepis diaspros* Fraser-Brünner, 1940 (Ben Amor & Capapé, 2008), and bluespotted cornetfish *Fistularia commersonii* (Rüppel, 1835) (Rafrafi-Nouira *et al*., 2011). Additionally, *S. luridus* and *S. rivalutus* should be included among the non-native species which successfully develop and reproduce in their new area.

DODATNI ZAPISI O POJAVLJANJU LESEPSKIH RIB KOSTNIC PRED TUNIZIJSKO OBALO (OSREDNJE SREDOZEMLJE)

Sihem RAFRAFI-NOUIRA & Moncef BOUMAÏZA
Laboratoire d'Hydrobiologie Littorale et Limnique, Université du 07 novembre à Carthage, Faculté des Sciences, Zarzouna, 7021 Bizerte, Tunisia

Christian REYNAUD & Christian CAPAPÉ
Laboratoire interdisciplinaire de Recherche sur la Didactique, l'Éducation et la Formation, E. A. 3749, case 77, Université Montpellier II, Sciences et Techniques du Languedoc, 34095 Montpellier cedex 5, France
E-mail: capape@univ-montp2.fr

POVZETEK

Med raziskavami pred severno tunizijsko obalo (v osrednjem Sredozemlju) so bili ulovljeni primerki treh lesepskih selivk: vrsta Hemiramphus far *(Forsskål, 1775), temni morski kunec* Siganus luridus *(Rüppell, 1829) in morski kunec vrste* Siganus rivulatus *Forsskål, 1775. Primerki so podrobneje opisani v pričujočem članku, v katerem so navedeni tudi rezultati morfometričnih meritev in merističnih štetij. Ugotovitve pričajo tudi o širjenju njihovega areala v regiji proti severu in v celotnem Sredozemskem morju proti zahodu.*

Ključne besede: ribe kostnice, Hemiramphidae, Siganidae, lesepska selivka, tunizijska obala, Sredozemlje

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ON THE ADDITIONAL OCCURRENCES OF THE IMPERIAL BLACKFISH, *SCHEDOPHILUS OVALIS* (CUVIER, 1833) (CENTROLOPHIDAE) IN THE ADRIATIC SEA

Jakov DULČIĆ
Institute of Oceanography and Fisheries, POB 500, HR-21000 Split, Croatia
E-mail: dulcic@izor.hr

Daria SKARAMUCA
University of Dubrovnik, Department for Aquaculture, HR-20000 Dubrovnik, Ćire Carića 4, Croatia

Branko DRAGIČEVIĆ & Robert GRGIČEVIĆ
Institute of Oceanography and Fisheries, POB 500, HR-21000 Split, Croatia

Višnja BUKVIĆ
HR-20350 Metković, Ante Starčevića 25, Croatia

Boško SKARAMUCA
University of Dubrovnik, Department for Aquaculture, HR-20000 Dubrovnik, Ćire Carića 4, Croatia

ABSTRACT

Additional records of imperial blackfish, Schedophilus ovalis *(Cuvier, 1833) in the Adriatic waters are herewith documented. These records increase the knowledge on the richness of the Adriatic marine ichthyofauna and may suggest an expansion of the geographical distribution of the species from southern to northern areas in the Adriatic.*

Keywords: *Schedophulus ovalis*, imperial blackfish, Centrolophidae, Adriatic Sea

NUOVE SEGNALAZIONI DI CENTROLOFO VIOLA, *SCHEDOPHILUS OVALIS* (CUVIER, 1833) (CENTROLOPHIDAE) IN MARE ADRIATICO

SINTESI

L'articolo riporta nuove segnalazioni della presenza del centrolofo viola, Schedophilus ovalis *(Cuvier, 1833), nel mare Adriatico. Tali dati vengono ad arricchire la conoscenza in merito alla ricchezza dell'ittiofauna marina adriatica. I risultati suggeriscono inoltre un'estensione della distribuzione geografica del centrolofo viola dalle aree meridionali a quelle settentrionali del mare Adriatico.*

Parole chiave: *Schedophulus ovalis*, centrolofo viola, Centrolophidae, mare Adriatico

INTRODUCTION

The imperial blackfish, *Schedophilus ovalis* (Cuvier, 1833) is present in the eastern and western-central Atlantic and throughout most of the Mediterranean (Haedrich, 1990). Wider distribution is reported in the literature, but due to conflicting records and issues with species identification, a revision of the genus is needed to establish a more accurate distribution (see Francour & Javel, 2003). Adult *S. ovalis* usually inhabit deeper waters at the edge of continental shelves and around oceanic islands while juveniles are epipelagic, often found in association with floating medusae or various floating objects (Quigley & Flannery, 2004**)**. Jardas (1996) noted that it is a very rare species in the Adriatic Sea. Dulčić *et al*. (2003) reported occurrences of the imperial blackfish only in the southern part of the Adriatic Sea.

In this paper we present additional records of this species (Fig. 1) with descriptions of the largest and the smallest specimen collected in the Adriatic Sea.

MATERIALS AND METHODS

On 15 April 2004, SCUBA divers observed 10 specimens of the imperial blackfish swimming under floating

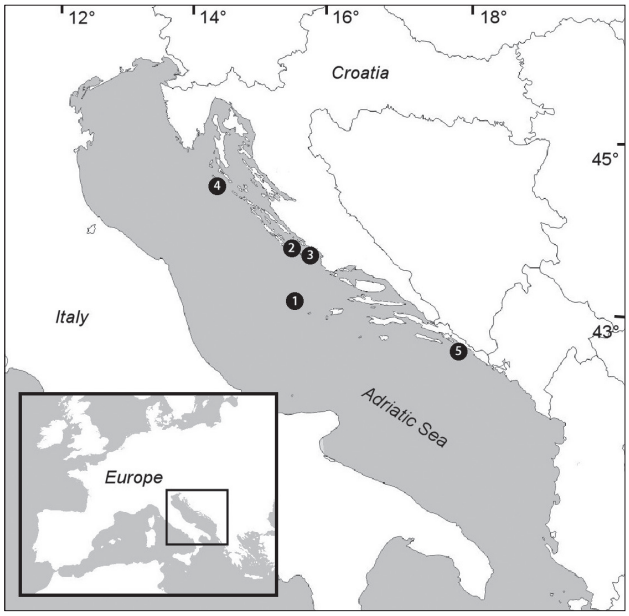

Fig. 1: Recent records of *Schedophilus ovalis* ***in the eastern Adriatic (see Table 1 for details).***
Sl. 1: Novejši podatki o pojavljanju vrste *Schedophilus ovalis* ***v vzhodnem Jadranu (glej Tabelo 1 za razlago).***

Tab. 1: Records of *Schedophilus ovalis* ***in the Adriatic Sea.***
Tab. 1: Zapisi o pojavljanju vrste *Schedophilus ovalis* ***v Jadranskem morju.***

Location (Source)	**Date**	**TL (cm)**	**No. specimens / Habitat / Remarks**
Korčula Island (southern Adriatic) (Kolombatović, 1902)	1902	-	1 specimen
20 NM SE from Dubrovnik (southern Adriatic) (V. Onofri, *pers. comm.*)	1979	25.2	1 specimen / at the surface by trawl
Pelješac Channel (southern Adriatic) (Onofri, 1986)	1982	-	1 specimen / at 2 m depth / with *Schedophilus medusophagus* and jellyfish *Pelagia noctiluca*
35 Nm SE from Dubrovnik (southern Adriatic) (Dulčić *et al.*, 2003)	28 July 2003	38.8	1 specimen / at 1 m depth / sea surface temperature 25.0 °C
SW off Jabuka Island (Pomo Pit) (middle Adriatic; this work) (Fig. 1, **1**)	15 April 2004	30-45	10 specimens / at 2 m depth / at the surface under floating buoy (visual census), with small *Balistes carolinensis* and *Trachurus* sp.
1 NM off Vrgada Island (this work) (Fig. 1, **2**)	21 April 2004	25-35	4 specimens / at about 1.5 m depth / fish close to farming cages (tuna)
1 NM off Murter Island (middle Adriatic; this work) (Fig. 1, **3**)	21 April 2004	around 40	1 specimen / at about 3 m depth / specimen close to farming cages (tuna)
Near Susak Island (northern Adriatic; this work) (Fig. 1, **4**)	5 April 2007	54.5	1 specimen ♂ / at about 40 m depth
Near Koločep Island (southern Adriatic; this work) (Fig. 1, **5**)	August 2010	9.3	1 specimen / at the surface

buoys near a vessel, together with small *Balistes carolinensis* and *Trachurus* sp. near the islet of Jabuka, (Pomo Pit) at a depth of about 2 m (Tab. 1).

On 21 April 2004, SCUBA divers observed 4 specimens of the imperial blackfish near Vrgada Island close to fish farming cages (*Thunnus thynnus*) at a depth of around 1.5 m, while 1 specimen was observed near Murter Island, also close to fish farming cages, at a depth of about 3 m.

One specimen of the imperial blackfish was captured in a trawl catch collected in the northern Adriatic (near Susak Island) on 5 April, 2007. All records were in regions further north than their previous record areas. The capture near Susak Island represents the northernmost record for this species in the Adriatic Sea and is also the largest documented specimen collected in the Adriatic. This capture and visual census observations might indicate a range extension of the species in the Adriatic Sea.

One specimen was caught in August 2010 near Koločep Island (Elafiti Archipelago, southern Adriatic) and it is the smallest documented specimen of this species in the eastern Adriatic (Fig. 2).

Tab. 2: Biometric and meristic data of** S. ovalis**.
Tab. 2: Biometrični in meristični podatki o vrsti** S. ovalis**.

Parameter	**Length(mm) / weight (g)**	**% of TL**	**% of head length**
TL (mm)	545 / 1230		
Maximum body depth	221.3	40.6	
Head length	142.8	26.2	
Predorsal length	112.8	20.7	
Preventral length	152.6	28	
Preanal length	283.4	52	
Eye diameter	30.7		21.5
Preorbital distance	44.3		31
Postorbital distance	83.1		58.2
Meristic data			
Dorsal fin rays	VIII+30		
Anal fin rays	III+22		
Pectoral fin rays	22		
Ventral fin rays	I+5		
Caudal fin rays	23		
Gill rakers on first arch	16+1+6		
Total length (mm)	92.7		
Maximum body depth	39.9	43	
Head length	32.3	34.8	
Predorsal length	21.2	22.9	
Preventral length	28.3	30.5	
Preanal length	54.6	58.9	
Eye diameter	7		21.7
Preorbital distance	10.3		31.9
Postorbital distance	18.7		57.9
Meristic data			
Dorsal fin rays	VIII+30		
Anal fin rays	III+22		
Pectoral fin rays	23		
Ventral fin rays	I+5		
Caudal fin rays	23		

RESULTS AND DISCUSSION

All specimens were identified in accordance with Jardas (1996) and Orsi Relini *et al.* (1990). Two specimens (total length (TL) = 54.5 cm, 9.3 cm) were deposited in the collection of the Institute of Oceanography and Fisheries in Split. The larger specimen caught near Susak was identified as an immature male based on a macroscopic inspection of the gonads. For morphometric data a board rule and a clock calliper (0.1 mm) were used. Meristic counts were also recorded for the largest and smallest specimens.

The specimen from Susak Island is 545 mm TL and 1230 g in weight, while the specimen from Koločep Island is 92.7 mm TL (Tab. 2). Standard counts and measurements fit well with the previous descriptions of the species, such as in Orsi Relini *et al.* (1990) and Haedrich (1990).

The measured and approximated sizes of individuals were all less than 45 cm TL in shallow water along the coast or offshore, but one was 54.5 cm TL at about a depth of 40 m. The size distribution according to depth corresponds to that reported by Orsi Relini *et al.* (1990): 60-106 cm TL at a depth > 500 m and 25-45 cm TL from the surface to a depth of 40 m. According to same authors, the size of the imperial blackfish specimen of about 45 cm TL corresponds to the first year of life, and taking this into consideration, all specimens from our study were probably immature (with age range between 0+ and 2+).

In the Adriatic, *S. ovalis* was recorded for the first time by Kolombatović (1902) near Korčula Island (southern Adriatic) who wrongly identified it as a new species naming it *Centrophilus corcyrensis* (Tab. 1). The second recorded specimen was caught in 1979 with a deep bottom trawl in the open waters of the southern Adriatic, about 20 NM SE from Dubrovnik (V. Onofri, *pers. comm.*). The third specimen (without measures) of the species was captured together with *S. medusophagus* in the Pelješac Channel (southern Adriatic) in 1982 (at a depth of 2 m) where jellyfish *Pelagia noctiluca* were also present in large quantities (Onofri, 1986). The last record was in 2003 in the open waters of the southern Adriatic, about 35 NM SE from Dubrovnik (Dulčić *et al.,* 2003). Recent records from this study might indicate an expansion of the geographical distribution of the species from southern to northern areas in the Adriatic and the number of observed specimens has significantly increased in recent years (Tab. 1). A continuous expansion of its distribution has already been documented in the

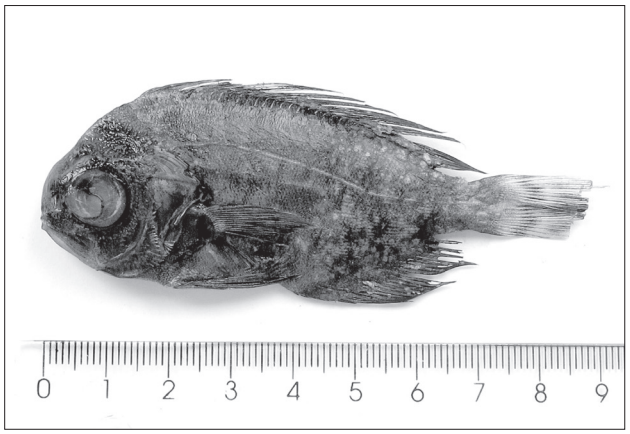

Fig. 2: The caught specimen of** S. ovalis **(Lt = 9.3 cm) in August 2010 near Koločep Island (Elafiti Archipelago, southern Adriatic).
Sl. 2: Primerek vrste** S. ovalis **(Lt = 9,3 cm), ujet v avgustu 2010 pri otoku Koločep (Elafitsko otočje, južni Jadran).

western Mediterranean during the last decade (Follesa *et al*., 2006). The distribution extension of *S. ovalis* in the Adriatic Sea could be explained by the warming of the Mediterranean waters (Dulčić *et al.,* 2003), as it has been assumed to account for the increasing occurrence of the imperial blackfish in other regions of the Mediterranean Basin (Francour & Javel, 2003; Corsini-Foka & Frantzis, 2009). Similar cases of distribution extensions are already known for some other fish species in the Adriatic (see Dragičević & Dulčić, 2010).

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NOVI PODATKI O POJAVLJANJU VRSTE *SCHEDOPHILUS OVALIS* (CUVIER, 1833) (CENTROLOPHIDAE) V JADRANSKEM MORJU

Jakov DULČIĆ
Institute of Oceanography and Fisheries, POB 500, HR-21000 Split, Croatia
E-mail: dulcic@izor.hr

Daria SKARAMUCA
University of Dubrovnik, Department for Aquaculture, HR-20000 Dubrovnik, Ćire Carića 4, Croatia

Branko DRAGIČEVIĆ & Robert GRGIČEVIĆ
Institute of Oceanography and Fisheries, POB 500, HR-21000 Split, Croatia

Višnja BUKVIĆ
HR-20350 Metković, Ante Starčevića 25, Croatia

Boško SKARAMUCA
University of Dubrovnik, Department for Aquaculture, HR-20000 Dubrovnik, Ćire Carića 4, Croatia

POVZETEK

Avtorji poročajo o novih najdbah ribje vrste Schedophilus ovalis *(Cuvier, 1833) v jadranskih vodah. Ti podatki dopolnjujejo poznavanje o pestrosti jadranske ribje favne in obenem kažejo na širjenje areala južnih jadranskih vrst proti severnim predelom Jadranskega morja.*

Ključne besede: *Schedophulus ovalis*, Centrolophidae, širjenje proti severu, Jadransko morje

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BIOMETRIC PROPERTIES OF AXILLARY SEA BREAM, *PAGELLUS ACARNE* (OSTEICHTHYES: SPARIDAE), FROM THE EASTERN ADRIATIC SEA

Branko DRAGIČEVIĆ, Jakov DULČIĆ & Robert GRGIČEVIĆ
Institute of Oceanography and Fisheries, POB 500, HR-21000 Split, Croatia
E-mail: brankod@izor.hr

ABSTRACT

A sample of 266 specimens of the axillary seabream Pagellus acarne *(Risso, 1826) from the eastern Adriatic Sea was biometrically analysed. Total length of all specimens ranged from 9.3-9.5 cm. Eighteen morphometric and seven meristic characteristics were obtained. Changes in morphological relations with growth of the fish were studied in order to describe relative growth of the axillary seabream. Data from this study indicate that certain differences between populations of* P. acarne *from the Adriatic Sea and the eastern Atlantic might exist.*

Keywords: *Pagellus acarne*, Sparidae, biometry, morphology, meristics, Adriatic Sea

PROPRIETÀ BIOMETRICHE DI PAGELLO BASTARDO, *PAGELLUS ACARNE* (OSTEICHTHYES: SPARIDAE), DELL'ADRIATICO ORIENTALE

SINTESI

Gli autori riportano i risultati dell'analisi biometrica di un campione di 266 esemplari di pagello bastardo, Pagellus acarne *(Risso, 1826), pescato nell'Adriatico orientale. La lunghezza totale degli individui è risultata fra 9,3 e 29,5 cm. Nell'articolo vengono evidenziate 18 caratteristiche morfometriche e sette meristiche. Al fine di descrivere la crescita relativa del pagello bastardo, sono state inoltre studiate le variazioni morfologiche in relazione alla crescita. I risultati dello studio indicano possibili differenze fra le popolazioni di* P. acarne *dell'Adriatico e dell'Atlantico orientale.*

Parole chiave: *Pagellus acarne*, Sparidae, biometria, morfologia, meristica, mare Adriatico

INTRODUCTION

Axillary seabream, *Pagellus acarne* (Risso 1826) is a sparid fish distributed throughout the eastern Atlantic (from the North Sea to Senegal) and in the entire Mediterranean Sea. It is a demersal species, inhabiting various types of sea bottoms, but is more common on soft bottoms and seagrass beds (Bauchot & Hureau, 1986). It is distributed throughout the Adriatic Sea, but is considered relatively rare (Jardas, 1996). According to Jardas *et al*. (2008) the status of the species was evaluated as of Least Concern (LC). The axillary seabream is a protoandric hermaphroditic species (Bauchot & Hureau, 1986) and aspects of its biology are still poorly known for the Adriatic Sea. Although a considerable amount of information about its biology is present in the literature, there is a scarcity of information on its morphological properties *i.e*. morphometry and meristics.

Reproduction, age and growth of *P. acarne* from the Canarian archipelago were studied by Pajuelo & Lorenzo (1999), from the Spanish waters by Velasco *et al*. (2011) and from the Portugese waters by Coelho *et al*. (2005) and Santos *et al*. (1995). A diet of axillary seabream from Tunisian waters was studied by Fehri-Bedoui *et al*. (2009), from central eastern Atlantic by Domanevskaya & Patokina (1984) and from the Azorean archipelago by Morato *et al*. (2001). Le-Trong & Kompowski (1972) provided, among various other aspects of biology of *P. acarne*, a brief overview of its morphological characteristics for the north-west African region.

Knowledge of the biometry of the species is essential for providing a more accurate description of the species, while differences in morphological parameters in different regions might indicate distinctiveness of populations of the same species.

The aim of this study was to investigate morphological properties of the axillary seabream from the eastern Adriatic by analysing its morphometric and meristic characters and variations of these parameters in relation to its growth.

MATERIALS AND METHODS

A total of 266 specimens of axillary seabream were collected for this study in the period from July 2007 to July 2008. Specimens were collected using various fishing gear *i.e*., trammel nets, beach seines and trawlers at various locations in the eastern Adriatic Sea (Fig 1).

All body lengths were measured with dial calipers to the nearest 1 mm. Sex of the fish was determined macroscopically according to the appearance and shape of gonads and specimens were classified as male, female, hermaphrodite or immature. In all, 18 morphometric and 7 meristic characters were analysed.

Morphometric characters were as follows: total length (TL), standard length (SL), length of dorsal (LD) and anal fin base (LA), length of pectoral (LP), ventral (LV) and caudal fins (LC), pre dorsal (PD), preanal (PA), preventral (PV) and prepectoral (PP) distance, maximum (H) and minimum (h) body height, head length (CL), eye diameter (O) and preocular (PO), interocular (IO) and postocular distance (OLO). Meristic characters were as follows: number of rays in dorsal (D), pectoral (P), ventral (V), anal (A) and caudal (C) fins, number of gillrakers (Brsp) and number of scales in linea lateralis (L. Lat) (Fig. 2).

Analysis of biometry data was carried using arithmetic means, standard deviations and variability coefficients. Differences between mean values of morphometric characters of males and females were determined by Student's *t* test ($p < 0.05$).

Relative growth was analysed using linear regression between the morphometric relations and the total length of the fish. Statistical analysis was performed using the Statistica 7 software package and only regressions that

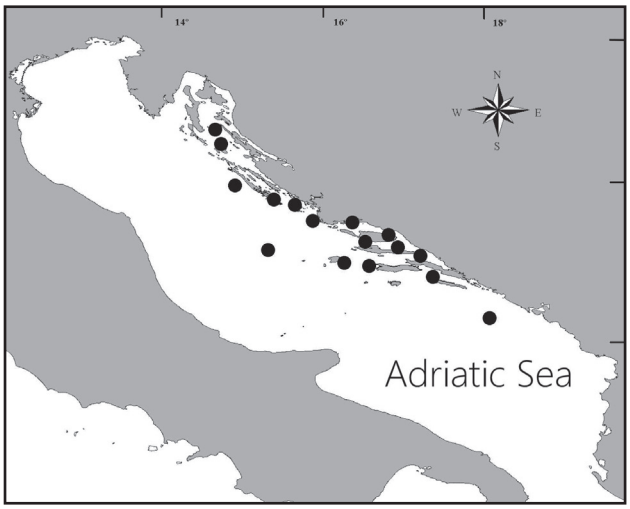

Fig. 1: Sampling locations of** P. acarne **in the eastern Adriatic Sea.
Sl. 1: Vzorčevalne lokalitete divjega ribona** P. acarne **v vzhodnem Jadranskem morju.

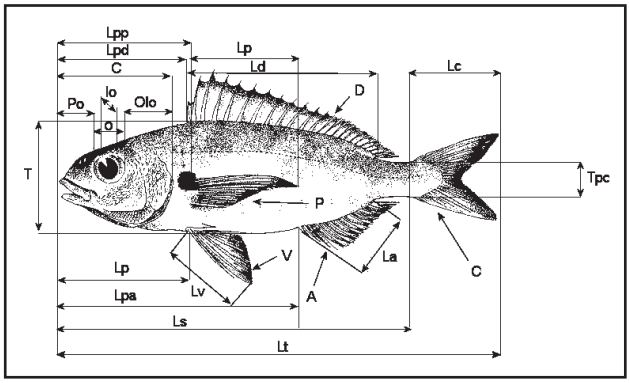

Fig. 2: Visual representation of morphometric characters examined in** P. acarne**.
Sl. 2: Preiskani morfometrični znaki pri divjem ribonu** P. acarne**.

Tab. 1: Relationships of morphometric characters (%) for males (n = 76), females (n = 99) and total sample (n = 266) of the axillary seabream, *Pagellus acarne* ***from the eastern Adriatic Sea. SD = standard deviation; V =variability coefficient.***

Tab. 1: Odnos med morfometričnimi znaki (%) za samce (n = 76), samice (n = 99) in celotni vzorec (n = 266) divjih ribonov *Pagellus acarne* ***iz vzhodnega Jadranskega morja. SD = standardna deviacija, V = koeficient variacije.***

Relationship	Sex	Range (%, mm)	Mean ± SD (mm)	t-value	V (%)
SL/TL	♂ ♀ Total	76.47-87.95 76.85-85.7 76.47-87.95	81.35 ± 1.67 81.77 ± 1.37 81.34 ± 1.51	1.64	2.05 1.68 1.86
CL/SL	♂ ♀ Total	26.02-31.38 27.23-32.66 25.86-32.66	29.35 ± 1.11 29.54 ± 1.20 29.38 ± 1.18	1.06	3.81 4.06 4.03
LD/SL	♂ ♀ Total	43.15-53.19 44.72-52.41 43.11-53.19	48.57 ± 1.88 48.25 ± 1.49 48.23 ± 1.74	1.24	3.87 3.10 3.60
LA/SL	♂ ♀ Total	13.70-18.24 13.48-17.68 12.94-19.27	16.19 ± 1.00 16.11 ± 0.82 16.14 ± 1.03	0.53	6.20 5.09 6.38
LP/SL	♂ ♀ Total	22-27.08 24.69-30.24 22-32.27	27.80 ± 1.62 27.90 ± 1.14 27.66 ± 1.49	1.09	5.83 4.11 5.42
LV/SL	♂ ♀ Total	13.33-19.39 14.01-18.66 13.33-19.51	16.97 ± 1.13 16.94 ± 0.91 16.89 ± 1.11	0.20	6.67 5.39 6.61
LC/SL	♂ ♀ Total	23.12-30.49 23.03-31.03 20.86-31.03	27.67 ± 1.37 27.62 ± 1.34 27.69 ± 1.46	0.22	4.96 4.88 5.27
PD/SL	♂ ♀ Total	29.45-37.03 30.62-38.18 29.45-39.47	33.52 ± 1.49 33.83 ± 3.82 33.85 ± 1.38	1.40	4.44 3.82 4.08
PA/SL	♂ ♀ Total	58.21-70.92 60.57-70.98 58.21-70.98	65.39 ± 1.92 65.59 ± 1.71 65.34 ± 1.75	0.53	2.94 2.61 2.68
PP/SL	♂ ♀ Total	28-36.29 29.06-34.50 27.70-36.29	32.02 ± 1.41 32.32 ± 1.14 32.15 ± 1.32	1.50	4.41 3.53 4.11
PV/SL	♂ ♀ Total	29.45-38.54 30.81-37.70 29.05-38.54	34.25 ± 1.65 34.41 ± 1.41 34.23 ± 1.50	0.69	4.83 4.10 4.39
H/SL	♂ ♀ Total	26.53-35.29 23.83-35 22.78-35.29	30.14 ± 2.00 29.70 ± 1.87 29.41 ± 2.14	1.49	6.65 6.30 7.29
h/SL	♂ ♀ Total	7.46-9.71 7.33-9.70 7.07-10.12	8.50 ± 0.57 8.40 ± 0.53 8.45 ± 0.63	1.16	6.81 6.38 7.48
O/CL	♂ ♀ Total	29.41-39.58 26.66-39.53 26.66-53.84	34.73 ± 2.70 34.52 ± 2.1 34.62 ± 2.60	0.54	7.78 6.08 7.51
IO/CL	♂ ♀ Total	16.27-30 20.40-28 16.27-30	23.93 ± 2.05 24.36 ± 1.80 24.22 ± 2.20	1.23	8.59 7.40 9.11
PO/CL	♂ ♀ Total	16.27-33.33 18.36-34.37 16.27-39.13	25.57 ± 3.41 25.97 ± 3.42 25.88 ± 3.49	0.76	13.34 13.18 13.49
OLO/CL	♂ ♀ Total	35-47.91 37.03-48.27 32.25-50	42.40 ± 2.60 42.32 ± 2.37 42.14 ± 2.82	0.21	6.14 5.61 6.71
h/H	♂ ♀ Total	24.39-32.55 25-32.55 24.39-40	28.26 ± 1.83 28.33 ± 1.39 28.88 ± 2.33	0.25	6.50 4.92 8.08

were statistically significant ($p < 0.05$) were accepted as indicators of decreasing ($b < 0$) or increasing ($b > 0$) relation.

RESULTS

Overall, 266 specimens of *P. acarne* were examined for morphometric and meristic characters. Of these, 99 were females, 76 were males, 77 were immature specimens and 14 specimens had equally developed male and female gonads and were considered hermaphrodites. Total length of all specimens ranged from 9.3 to 29.5 cm (18.62 ± 3.74), with females ranging from 16.2 to 29.5 cm (20.93 ± 2.79) and males from 15.5 to 25.7 cm (19.44 ± 2.13). Immature specimens ranged from 9.3 to 18.6 cm (14.3 ± 2.65) and hermaphrodite specimens from 16.5 to 25.5 cm (20.6 ± 2.95). There were no statistically significant differences in any of 18 morphometric characters between the sexes.

Range of morphometric characters, arithmetic mean, standard deviation, *t*-value and variability coefficient are presented in Table 1. Variability coefficients were in the range from 1.68 (SL/TL) to 13.49 (PO/CL).

Meristic data are shown in Table 2. In all specimens ventral fin was composed of six rays while other meristic properties showed slight variations among specimens.

The coefficients of linear regression showed that bigger *P. acarne* have relatively shorter predorsal distance ($b = -0.026$) and smaller eye diameter ($b = -0.0948$) while standard length ($b = 0.112$), dorsal fin base length ($b = 0.083$), pectoral fin length ($b = 0.118$), preanal fin distance ($b = 0.106$), preventral fin distance ($b = 0.080$), maximum body height ($b = 0.363$), preocular distance ($b = 0.192$) and postocular distance ($b = 0.062$) are relatively larger in bigger specimens.

DISCUSSION

This study presents first data on the morphometric and meristic properties of *P. acarne* from the Adriatic Sea. Moreover, only a few publications report on the biometric properties of this species and they do so in more general terms (Le-Trong & Kompowski, 1972; Bauchot & Hureau, 1986).

Morphometric differences between sexes were not found which might be due to protandric hermaphroditism of this species. Namely, due to sequential hermaphroditism, the same individuals appear first as males and later as females. However, it is not uncommon to encounter some differences between sexes in hermaphroditic fishes. According to Smith & Heemstra (1986), dichromatism seems to be most highly developed in hermaphroditic fishes. Moreover, according to Pajuelo & Lorenzo (2000), a protogynic sparid species, *Spondyliosoma cantharus,* exhibits sexual dichromatism during the spawning season. It would be interesting to investigate whether some less obvious morphological or chromatic differences exist between males and females of axillary seabream.

It seems that with the exception for the number of rays in the ventral fin, which was the same as the number reported by Perez (1820), all other characters showed some differences at least in the range of encountered characters (Tab. 3). Additionally, the number of pectoral fin rays reported by Perez (1820) is higher than the number from this study. However, it is unclear as to what area Perez (1820) is referring, but beside the description of the species, it is stated that it is abundant mainly off Cadiz, Spain (Eastern Atlantic). Le-Trong & Kompowski (1972) reports that diameter of eye of *P. acarne* from the north-west African region can be accommodated 3-4 times in length of head, while the range of the same

Tab. 2: Meristic characters of** P. acarne **from the eastern Adriatic Sea (n = 266). SD = standard deviation; V = variability coefficient.
Tab. 2: Meristični znaki divjega ribona** P. acarne **iz vzhodnega Jadranskega morja (n = 266). SD = standardna deviacija, V = koeficient variacije.

Meristic character	Range	Mean ± SD	V (%)
No. rays in dorsal fin	XII 10-11	22.93 ± 0.23	1.00
No. rays in anal fin	III 9-11	12.95 ± 0.27	2.08
No. rays in pectoral fin	15-17	15.96 ± 0.24	1.50
No. rays in ventral fin	I 5	6.00 ± 0.00	0
No. rays in caudal fin	21-24	21.88 ± 0.54	2.46
No. branchiospines	23-29	25.62 ± 1.22	4.76
No. scales in linea lateralis	66-73	69.70 ± 1.60	2.29

Tab. 3: Overview of meristic characters reported for** P. acarne **from this study and from other sources.
Tab. 3: Pregled merističnih znakov, objavljenih za divjega ribona** P. acarne **iz te raziskave in drugih virov.

Meristic character / author, area	This study, Adriatic Sea	Le-Trong & Kompowski (1972), north-west African region, eastern Atlantic	Perez (1820), probably eastern Atlantic, Spanish coast	Bauchot & Hureau (1986), general description, area not indicated
No. rays in dorsal fin	XII 10-11	XII 9-11	11-12	XII-XIII 10-12
No. rays in anal fin	III 9-11	III 9-11	III 10	III 9-10
No. rays in pectoral fin	15-17	-	19	-
No. rays in ventral fin	I 5	-	I 5	-
No. rays in caudal fin	21-24	-	22	-
No. branchiospines	23-29	-	-	21-28
No. scales in linea lateralis	66-73	68-72	-	65-72

relation from our study is 1.85-3.75. Furthermore, Le--Trong & Kompowski (1972) reported ranges of IO/LT (6.35-9.10 *vs*. 2.84-7.05 from our study), O/LT (6.55-9.50 *vs*. 6.46-9.75) and PO/LT (3.30-5.10 *vs*. 4.09-9.6). As can be seen, ranges of IO/LT and PO/LT differed from those from this study, whereas O/LT was quite similar.

It is interesting to note that Le-Trong & Kompowski (1972) investigated the morphological properties of *P. acarne* from two adjacent areas – the Cap Blanc region and the Rio de Oro region (western African coast) and found that some morphological differences exist in the previously mentioned characters. Due to observed differences in morphology, rate of growth, condition and period of sex change, they concluded that within the investigated region, at least two separate stocks of this species exist. Differences between our study and that of Le-Trong & Kompowski (1972) might be due to the differing length range of fish subjected to investigation (17-35 cm *vs*. 9.3-29.5 cm) or due to some other reasons *i.e.,* imperfection of measurements or real morphological differences between adjacent populations.

Higher variability coefficients were found for morphometric characters related to head length. This is especially the case with PO/CL relation (> 13 %). Ferri *et al*. (2010) also encountered higher variability coefficients related to head length in *Scorpaena porcus*. All other coefficients were lower than 10 %. According to Carvalho (1993), values of this coefficient within populations are usually far greater than 10 %. Lower coefficients reported in this study might indicate low intra-population variation, but this should be confirmed with further studies.

This study may indicate that some morphological differences exist between populations of *P. acarne* from the Adriatic Sea and those from the north-west African region, but more elaborate research should be undertaken to conclude that such differences really do exist. Although no evidence of morphological differences between males and females were found in this study, it is possible that such differences exist in some other aspects such as coloration.

BIOMETRIČNE ZNAČILNOSTI DIVJEGA RIBONA, *PAGELLUS ACARNE* (OSTEICHTHYES: SPARIDAE), IZ VZHODNEGA JADRANSKEGA MORJA

Branko DRAGIČEVIĆ, Jakov DULČIĆ & Robert GRGIČEVIĆ

Institute of Oceanography and Fisheries, POB 500, HR-21000 Split, Croatia
E-mail: brankod@izor.hr

POVZETEK

Avtorji so analizirali biometrične značilnosti 266 primerkov divjega ribona Pagellus acarne *(Risso, 1826) iz vzhodnega Jadranskega morja. Celotna dolžina vseh primerkov je bila 9,3–29,5 cm. Izmerili so 18 morfometričnih in 7 merističnih značilnosti. Raziskali so spremembe morfoloških odnosov z rastjo rib z namenom, da bi opisali relativno rast divjega ribona. Podatki te raziskave kažejo na možne določene razlike med populacijami divjih ribonov iz Jadranskega morja in vzhodnega Atlantika.*

Ključne besede: *Pagellus acarne*, Sparidae, biometrija, morfologija, meristika, Jadransko morje

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THE RELATIONSHIP BETWEEN FISH LENGTH AND OTOLITH DIMENTIONS OF MUGILID FISH, *LIZA KLUZINGERI* (DAY, 1888) COLLECTED FROM THE PERSIAN GULF NEAR BANDAR ABBAS

Laith JAWAD
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, PO Box 427, Post Code 100, Muscat, Sultanate of Oman
E-mail: laith_jawad@hotmail.com

Zahra SADIGHZADEH
Department of Marine Biology, Graduate School of Marine Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran

Haithem AL-BUSAIDI
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, PO Box 427, Post Code 100, Muscat, Sultanate of Oman

ABSTRACT

The relationships between otolith dimensions and fish size (total length and fork lengths) for the teleost species, Liza klunzingeri *(Day, 1888) collected from the vicinity of Bandar Abbas, Persian Gulf were examined and found to be linear. Otolith morphometric observations including length, width and weight were correlated with the total and fork lengths of the fish. The length, width and weight of the otolith appeared to be good criteria to estimate total and fork length of fish as well as the easiest parameters to measure.*

Keywords: otolith dimensions, fish length, *Liza klunzingeri*, Persian Gulf, Iran

RELAZIONE FRA LUNGHEZZA TOTALE E DIMENSIONI DELL'OTOLITE NEL MUGILIDE *LIZA KLUZINGERI* (DAY, 1888) CATTURATO NEL GOLFO PERSICO VICINO A BANDAR ABBAS

SINTESI

Le relazioni tra dimensioni di otoliti e taglia (lunghezza totale e lunghezza alla biforcazione) per la specie Liza klunzingeri *(Day, 1888), raccolta nelle vicinanze di Bandar Abbas, nel Golfo Persico, sono state esaminate e ritenute lineari. Le misurazioni morfometriche degli otoliti, inclusi lunghezza, larghezza e peso, sono state correlate con le lunghezze totali e le lunghezze alla biforcazione dei pesci. Lunghezza, larghezza e peso dell'otolite risultano essere buoni criteri di stima per la lunghezza totale e la lunghezza alla biforcazione, nonché i parametri più facili da misurare.*

Parole chiave: dimensioni otoliti, lunghezza totale del pesce, *Liza klunzingeri*, Golfo Persico, Iran

INTRODUCTION

In all bony fishes (Osteichthyes) there are three pairs of otoliths, or ear stones: the sagittae, asteriscus, and lapillus. Otoliths are mineral inert components made of calcium carbonate in the form of aragonite, in a protein matrix. They are located within the inner ear where they contribute to several physiological processes such as audition, mecano-reception and equilibration (Popper & Coombs, 1980) which allow fishes to achieve a better perception of their own environment. Except in Cypriniformes and Siluriformes, the sagittae are the largest pair of otoliths in most bony fishes (Paxton, 2000). Ichthyologists have used otoliths and in particular sagittae in registering the information of age, reproduction and migration (Morat *et al*., 2008). Otoliths are also involved in ecological studies (Campana, 2005), stock assessments (Tracey *et al*., 2006, Gonzalez-Salas & Lenfant, 2007), and determination of the diet of predatory fishes (Lilliendahl & Solmundsson, 2006).

The demonstration of the significant positive relationship between otolith size and fish size could go back seventy years ago with Trout (1954) and Templemann & Squires (1956), who attempted to study this relationship in the cod species *Borreogadus saida* and haddock *Melanogrammus aeglefinus*.

For most species, the relationship between otolith dimensions and fish length can be described by a simple linear regression. Otolith weight also has been correlated with fish length (Hunt, 1979; Lychakov *et al*., 2006).

Otolith dimensions and weight-fish length relationship studies have not been conducted for Iranian fishes. Thus, this information is needed for research on resources used by an early Iranian dietary analysis of fish eaters, and a reconstruction of ancient marine environments.

The aim of the present study is to provide data about the relationship between otolith size (length and width) and weight and fish length of the teleost fish, *Liza klunzingeri* collected from the vicinity of Bandar Abbas, Persian Gulf. The data offers a helpful tool for feeding studies and also gives support to palaeontologists in their investigation on fossils.

MATERIALS AND METHODS

Adult fish specimens were collected on 3rd July 2007 from the coastal waters of Bandar Abbas, Persian Gulf. All specimens were identified according to Randall (1995) and then they were examined for total length (TL) and fork length (FL) to the nearest millimetre. The total number of sagittae used in this research was 92 with three replicates for each length size. Sagittae were removed through a cut in the cranium to expose them and then cleaned and stored dry in glass vials. The left and right otoliths were measured using digital callipers and recorded separately. Specimens with obvious evidence of calcite crystallization (Strong *et al*., 1986) or other aberrant formations were rejected. Each sagittae, systematically placed with the sulcus acusticus oriented through the observer and its length and width were determined using digital callipers and defined as the longest and widest dimensions between the rostrum and postrostrum axis respectively (nomenclature of Smale *et al*., 1995) and width as the dimensions from the dorsal to ventral edge taken at right angles to the length through the focus of the otolith. Individual otolith mass was determined to the nearest milligram using an electronic weigh scale. The relationship between otolith length, width, weight and fish lengths (TL and FL) were determined using least squares regression analysis.

RESULTS

The range of the total and fork lengths of the specimens used in this study was 121-178 mm, and 111-167 mm respectively with a mean of 152.1, 117.6 mm respectively. The fish lengths available for the species in question were those observed in commercial fisheries

Tab. 1: Results of the regression analysis of the difference between left and right otolith dimension on total length and fork lengths of *L. klunzingeri*.
Tab. 1: Regresija razlike med merami levega in desnega otolita ter celotno dolžino in dolžino do repne zajede pri vrsti *L. klunzingeri*.

Parameter	Intercept	Slope	Correlation	Significance
Total length				
Otolith Length	15.215	0.228	0.001	not significant
Otolith Width	15.208	0.881	0.005	not significant
Otolith Weight	15.167	141.72	0.008	not significant
Fork Length				
Otolith Length	13.996	0.342	0.004	not significant
Otolith Width	14.019	0.884	0.006	not significant
Otolith Weight	13.965	126.99	0.007	not significant

and research surveys but the extremes of length ranges were under-sampled.

Regression of the difference between left and right otolith on fish total length indicated slopes not significantly different from zero with 0.001, 0.005, 0.008 correlations for length, width and weight respectively. Correlations not significantly different from zero were also obtained for the regression of the difference between the left and right otolith on fork length with 0.001, 0.006, 0.007 correlation for otolith length, width and weight respectively. Results of regression analysis are given in Table 1. The range in observed values for otolith length, width and weight of the species in question are 4.5-6.7 mm, 2.1-3.30 mm and 0.007-0.013g respectively.

A linear regression model was used to determine the relationship between the fish total and fork lengths and the sagittae dimensions used in the present study. For both fish total length and fork length, the otolith weight regression model appeared to adequately describe this relationship with both high correlation and significant estimates for slopes and intercepts (Tab. 2).

DISCUSSION

Paxton (2000) recognised an arbitrarily otolith size range. In this range, he suggested that a small to moderate otolith has a range of 2-5 % SL. The results of the present study showed that the otolith of *Liza klunzingeri* has a size ranging between 4.9-5.0 of % SL which falls near the top upper limit of the small to moderate otolith category from Paxton (2000). The species in question is a benthic species, living in shallow areas (Froese & Pauly, 2010). It has moderate sized eyes as well as moderate sized otoliths with a strong sense of hearing. Lombarte & Cruz (2007) suggested that the importance of acoustic communication is correlated with a moderate to large otolith size in a benthic environment in order to compensate for the reduction of light with depth. Therefore, it might not possible to separate the evolutionary history completely from the habitat (Paxton, 2000), as evidenced from the taxonomic grouping of the species of the fish families.

Results indicated that otolith linear dimensions and weight were related to fish length by a linear regression model and the increases in linear dimensions and weight appeared to keep pace with increases in fish length. These results agree with those of Hunt (1979) on several species collected from Northwest Atlantic Ocean and several other authors (Harvey *et al.*, 2000; Morat *et al.*, 2008). This linear relationship will continue until the fish reaches a maximum size; thereafter the otolith increases only in thickness (Aydin *et al.*, 2004). However, the level of this correlation also depends on some other factors such as feeding and habitat conditions (Beamish & McFarlen, 1987; Geldiay & Balik, 1996).

The lack of significant difference between the left and right otolith is consistent with the observation that the otolith pair are mirror images of each other (Hunt, 1979).

A relationship between otolith dimension and fish length has been used in identifying prey size from stomach content samples (Ross, 2005). Harkonen (1986) discusses some of the problems associated with this technique. Unlike other authors (*e.g.*, Hunt, 1979), results of this study suggested that otolith dimensions and weight are considered the most appropriate for this task.

Ross (2005) has stated some sources of error in the estimation of fish size from otolith size and has suggested they should be recognized. The linear otolith-length

***Tab. 2: Results of the regression analysis of total length, fork and standard length** vs. **otolith dimensions of** L. klunzingeri.*
***Tab. 2: Regresija med celotno dolžino, dolžino do repne zajede in standardne dolžine in merami otolitov pri vrsti** L. klunzingeri.*

Parameter	Intercept	Slope	Correlation
Total length			
Otolith length	5.363	1.728	0.453
Otolith width	6.411	3.353	0.418
Otolith weight	12.976	156.07	0.506
Fork length			
Otolith length	4.349	1.694	0.456
Otolith width	5.206	3.352	0.437
Otolith weight	11.724	159.2	0.551
Standard length			
Otolith length	4.979	1.189	0.386
Otolith width	5.776	2.280	0.347
Otolith weight	10.281	103.310	0.399

to fish-length relationship may depend on the growth rate in some species (Secor & Dean, 1989; Mugiua & Tanaka, 1992) or become curvilinear in some larval or juvenile fishes (West & Larkin, 1987). Alternatively, the linear relation may change at intervals relative to fish size (Frost & Lowry, 1981) or ontogenetic stage (Hare & Cowen, 1995) in some species. Thus, extrapolation may lead to significant error in the estimation of fish size, although most of these error sources were identified from larval or early juvenile fishes. Erosion of the otolith recovered from faeces or regurgitated digestive pellets might add additional biases to the process of fish length estimation (Ross & Johnson, 2000).

Fish size versus otolith size relationships will be useful for researchers examining food habits of fish eaters and size of fish in archaeological samples. Many more species and sizes of fish should be sampled to cover the full ranges of fishes involved in these studies.

RAZMERJE MED DOLŽINO RIBE IN MERAMI OTOLITOV PRI CIPLJU VRSTE *LIZA KLUZINGERI* (DAY, 1888), ULOVLJENEM V PERZIJSKEM ZALIVU BLIZU BANDAR ABBASA

Laith JAWAD
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, PO Box 427, Post Code 100, Muscat, Sultanate of Oman
E-mail: laith_jawad@hotmail.com

Zahra SADIGHZADEH
Department of Marine Biology, Graduate School of Marine Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran

Haithem AL-BUSAIDI
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth, PO Box 427, Post Code 100, Muscat, Sultanate of Oman

POVZETEK

V članku smo preučili razmerje med merami otolitov in velikostjo ribe (celotno dolžino in dolžino do repne zajede) pri ribi kostnici Liza klunzingeri *(Day, 1888), ulovljeni v bližini Bandar Abbasa v Perzijskem zalivu, in ugotovili, da je linearno. Rezultati morfometričnih meritev dolžine, širine in teže otolitov so v korelaciji s celotno dolžino in z dolžino do repne zajede. Ugotovili smo, da so dolžina, širina in teža otolitov dobri kriteriji za oceno celotne dolžine in dolžine do repne zajede ter da so to parametri, ki jih je najlaže izmeriti.*

Ključne besede: mere otolitov, dolžina ribe, *Liza klunzingeri*, Perzijski zaliv, Iran

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FLUCTUATING ASYMMETRY IN THE OTOLITH LENGTH, WIDTH AND THICKNESS IN TWO PELAGIC FISH SPECIES COLLECTED FROM THE PERSIAN GULF NEAR BANDAR ABBAS

Laith JAWAD
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth,
PO Box 427, Post Code 100, Muscat, Sultanate of Oman
E-mail: laith_jawad@hotmail.com

Zahra SADIGHZADEH
Department of Marine Biology, Graduate School of Marine Science and Technology, Science and Research Branch,
Islamic Azad University, Tehran, Iran

Dawood AL-MAMARY
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth,
PO Box 427, Post Code 100, Muscat, Sultanate of Oman

ABSTRACT

Asymmetry was calculated for the otolith length, width, and thickness of two pelagic fish species, Sardinella sindensis *(Clupeidae) and* Sillago sihama *(Sillaginidae). The results showed that the level of asymmetry of the otolith width was the highest among the two asymmetry values obtained for the otolith of* S. sindensis. *For* S. sihama*, otolith thickness showed the highest value among the three otolith measurements. The asymmetry value was zero for the otolith thickness in* S. sindensis. *The lowest and highest values of asymmetry for the three otolith measurements are recorded in the following fish size classes of* S. sindensis*: for otolith length, 9.0-9.9 mm and 14.0-14.9 mm respectively; for otolith width, 9.0-9.9 mm, 14.0-14.9 mm respectively. In* S. sihama*, for otolith length, 19.0-20.9 mm. and 21.0-22.9 mm. respectively, for otolith width, 15.0-16.9 mm and 25.0-26.9 mm respectively; for otolith thickness, 17.0-18.9 mm and 19.0-20.9 mm respectively. The possible cause of asymmetry in these two species has been discussed in relation to different pollutants and their presence in the area. The trend of an increase in the asymmetry value with the fish length was noticed in the width of the otolith of the two species studied.*

Key words: asymmetry, otolith, *Sardinella, Sillago*, Persian Gulf, Iran

ASIMMETRIA FLUTTUANTE IN LUNGHEZZA, LARGHEZZA E SPESSORE DI OTOLITE IN DUE SPECIE DI PESCI PELAGICI DEL GOLFO PERSICO, VICINO A BANDAR ABBAS

SINTESI

L'asimmetria è stata calcolata per lunghezza, larghezza e spessore degli otoliti di due specie di pesci pelagici, Sardinella sindensis *(Clupeidae) e* Sillago sihama *(Sillaginidae). I risultati hanno evidenziato che per l'otolite di* S. sindensis*, l'asimmetria era presente per due parametri, e il livello di asimmetria è risultato massimo per la larghezza dell'otolite. Per* S. sihama*, il valore più alto di assimetria si è registrato per lo spessore dell'otolite. Per* S. sindensis *invece, il valore dell'asimmetria per lo spessore degli otoliti era pari a zero. Sempre per* S. sindensis*, i valori minimo e massimo di asimmetria si sono registrati nelle seguenti classi di grandezza: per la lunghezza degli otoliti pari a 9,0-9,9 mm e 14,0-14,9 mm rispettivamente, e per la larghezza degli otoliti pari a 9,0-9,9 mm e 14,0-14,9 mm rispettivamente. Per* S. sihama*, i valori minimo e massimo di asimmetria si sono registrati per la lunghezza degli otoliti pari a 19,0-20,9 mm e 21,0-22,9 mm rispettivamente, per la larghezza degli otoliti pari a 15,0-16,9 mm e 25,0-26,9 mm rispettivamente, nonché per lo spessore degli otoliti pari a 17,0-18,9 mm e 19,0-20,9 mm rispettivamente. La possibile causa di asimmetria in queste due specie è stata messa in relazione a diverse sostanze inquinanti e alla loro presenza nella zona. Per entrambe le specie, gli autori hanno registrato una tendenza all'aumento del valore di asimmetria in relazione alla lunghezza del pesce.*

Parole chiave: asimmetria, otolite, *Sardinella, Sillago*, Golfo Persico, Iran

INTRODUCTION

Asymmetry is the differential development of a bilateral character between the sides of an organism (Van Valeen, 1962; Palmer & Strobeck, 1986; Leary & Allendorf, 1989). In many instances, developmental instability, which is the inability of an organism to compensate for disturbances during development (Zakharov, 1992), can be reflected by fluctuation asymmetry which is a random deviation from a perfect bilateral system (Palmer, 1994; Fey & Hare, 2008). Developmental instability ia affected by stress related to environmental or genetic conditions. Taking into consideration environmental stress which causes developmental instabilities; high fluctuating asymmetry could indicate the lower condition of larvae which experienced unfavourable environments. Thus, the method could show the specific environmental effects on the condition of the organism.

The relationship between fish condition and fluctuating asymmetry has been studied for adult fishes, and a number of measurements have been analysed, including the number of gill rakers, pectoral fin rays, fish body proportions, eye spot area, or otolith size and shape (Al--Hassan *et al.,* 1990; Al-Hassan & Hassan,1994; Escós *et al.,*1995; Somarakis *et al.,* 1997a, b; Jawad, 2001; Gonçalves *et al.,* 2002; Øxnevad *et al.,* 2002; Jawad, 2003, 2004).

This work studied fluctuating asymmetry in the otolith length, width, and thickness of the teleost fish *Sillago sihama* and otolith length and width of *Sardinella sindensis* collected from the Persian Gulf near Bandar Abbas as such studies were never performed on fish from Iranian waters. The Bandar Abbas locality was chosen as it considered among the important fishing grounds for the species in question (Al-Alawi, 2002). An asymmetry study of these two species is important in order to know the effects of this phenomenon on the settlement of the larvae of these species in this important fishing ground.

MATERIAL AND METHODS

Description of the sampling area

Bandar Abbas City, Iran (27° 03′ 46.43″ N, 56° 54′52.29″ E), capital of Hormozgan province is located in the middle of the strait of Hormoz. The port of Bandar Abbas links the Persian Gulf to the Sea of Oman and is located 1.501 km southwest of the capital, Tehran City. The fish sample was obtained from an area southwest of the Bandar Abbas Port (26° 46′ 52.18″ N, 56 ° 35′ 44.04″ E).

The characteristic features of the climate in Bandar Abbas in the summer are heat and humidity. Winters are moderate. The maximum temperature in summer can reach up to 49 °C while in winter the minimum temperature drops to about 5 °C. The annual rainfall is around 251 mm and the relative humidity is 66 %. The movement of sea currents, as in the other part of the Persian Gulf, is anticlockwise.

The annual average surface temperature of the water is 26.5 °C with a maximum temperature of more than 50 °C and a minimum temperature in winter of 3 °C. Fluctuations in the temperature at/near shore areas are higher, exceeding 20 °C (16-36 °C) than at the open Gulf areas (17-34 °C). Salinity varies between 36.5-37.

Sample collection

Samples were collected with a gill net on 13 July 2007 from the waters at Badar Abbas. A total of 130 specimens of adult *S. sidensis* and 120 specimens of *S. sihama* were examined. Fish total length was measured to nearest mm using a measuring board. Species were identified according to Randall (1995). Using digital callipers, otoliths were measured to the nearest mm. Otolith length, width and thickness were used to study the asymmetry level in the fish species.

Tab. 1: Squared coefficient of asymmetry (CV^2_a) value and character means (X_{r+l}) of** S. sindensis **and** S. sihama**.
Tab. 1: Vrednost kvadrata koeficienta asimetrije (CV^2_a) in srednja vrednost lastnosti (X_{r+l}) pri vrstah** S. sindensis **in** S. sihama**.

Character	CV^2_a	X_{r+l}	N	% of individuals with asymmetry
Sardinella sindensis				
Otolith length	2.1	2.1	130	13.3
Otolith width	9.0	0.9	130	10.0
Otolith thickness	0	0.3	130	0
Sillago sihama				
Otolith length	2.9	7.7	120	59.3
Otolith width	21.6	3.9	120	66.7
Otolith thickness	66.7	1.8	120	33.3

Statistical analysis

The statistical analysis was based on the squared coefficient of asymmetry variation (CV^2_a) for the three otolith dimensions according to Valentine *et al*. (1973):

$CV^2_a = (S_{r-l} \text{ X } 100/X_{r+l})^2$

where S_{r-l} is the standard deviation of signed differences and X_{r+l} is the mean of the character, which is calculated by adding the absolute scores for both sides and dividing by the sample size.

RESULTS

In the present study, fluctuating asymmetry was not correlated with sex asymmetries developed in the early stages of fish life where larvae are not recognizable sex-wise and any compensational growth during the larval stage cannot correct it. This is because such anomalies persist and became a source of stress to the individual further on in its life.

The results of asymmetry data analysis of the otolith length, width and thickness of *S. sindensis* and *S. sihama* collected from the waters around Badar Abbas, Persian Gulf are shown in Table 1. The results showed that the level of asymmetry was high for the otolith width and absent for the thickness of *S. sindensis*. As for *S. sihama*, the asymmetry value of the otolith thickness was the highest among the three otoliths measurements investigated. The asymmetry value was zero for the otolith thickness of *S. sindensis*.

For the specimens examined of *S.sindensis*, the lowest value of asymmetry was noticed in fish ranging in length between 9.0-9.9 mm and the highest level was showed in specimens in length ranging between 14.0-14.9 mm. While to *S. sihama*, the lowest and highest asymmetry values were reported for fish length groups 19.0-20.9 mm and 25.0-26.9 mm respectively. However, no asymmetry of the three otolith parameters was observed in the several size classes examined for both species.

The percentage of the individuals showing asymmetry in the otolith width was the highest among the percentages obtained for the three otolith characters studied of the two species in question (Tab.1). Individuals of *S. sindensis* and *S. sihama* were grouped into size classes (Tab. 2). The trend of an increase in the asymmetry value of the fish length was noticed in the width of the otolith of the two species studied.

DISCUSSION

Animal fitness is negatively correlated with asymmetry of morphological character in a large number of animal taxa (*e.g.* Møller & Nielsen, 1997; Martin & Lopez, 2001; Bergstrom & Reimchen, 2003). So far, there is a lack of information on the possible effects of asymmetry on the dispersal and recruitment of individuals (Matessi, 1997; Breuker *et al*., 2007). In fishes, the individual loses the ability to integrate with the habitat they are living in when they experience abnormal swimming activity (Helling *et al.,* 2003) and interference with correct sound localization (Lychakov & Rebane, 2005) as a result of the bilateral asymmetry in the otolith mass.

The results of this study present basic information about the variations in the dimensions of the otoliths of *S. sindensis* and *S. sihama,* such variations no matter how small, can affect the capability of young individuals to locate and settle in their suitable habitats (Gagliano & McCormick, 2004; Gagliano *et al*., 2008). Due to the asymmetry observed in the width of the otolith of *S. sindensis* and the otolith thickness of *S. sihama*, the settlement of those larvae might have been affected. Both *S. sindensis* and *S. sihama* are considered among the most commercial species in Iran, thus, further studies on these two species has to follow the variation of the asymmetry in the otolith of the larvae and its relation to the settlement process in their environment.

The high asymmetry value of the otolith width and thickness might indicate the vulnerability of the individual that, under conditions of stress, may develop an asymmetry in these two otolith characters. However, based on previous studies in this field, it is possible to conclude that there is a direct correlation between environmental stress due to pollution and asymmetry in the morphology of this species. Such environmental factors are present in the Persian Gulf waters in general (De Mora *et al.,* 2004) and the Iranian coasts of the Persian Gulf in particular (Fowler, 1993; Zahed, 2002; Pourebrahim & Yavari, 2003; Vossoughi *et al.,* 2005; Haapkylä *et al.,* 2007; Zahed *et al.,* 2010). On the other hand, the low asymmetry value displayed by the otolith characters studied in this work might be explained on the basis that these characters are less vulnerable to environmental stresses.

The origin and cause of asymmetry in fishes can depend on several factors, one of which is genetic factors which might be responsible for the asymmetry in these two characters, but these cannot be discussed at this stage due to the lack of genetic data on the ichthyofauna of Iran. The other possible factor is the environmental stress which leads to an increased level of asymmetry, but which might occur at low levels before causing wide spread death (Bengtsson & Hindberg, 1985).

Environmental stress can originate from pollution of sea water and sediments by hydrocarbons, heavy metals, pesticides and organic matter. Such a state of pollution became a usual event for the environment of the Persian Gulf coasts of Iran where different pollutants were reported to affect its water for at least the last twenty years (Fowler, 1993; Zahed, 2002; Pourebrahim & Yavari, 2003; Vossughi *et al.,* 2005; Haapkylä *et al.,* 2007; Zahed *et al.,* 2010).

Environmental causes might be natural and various pathogens and various population phenomena appeared to be producing nutritional deficiencies (Bengtsson

Tab. 2: Squared coefficient of asymmetry (CV^2_a) value and character means (X_{r+l}) by size class (in mm) of** S. sindensis **and** S. sihama**.
Tab. 2: Kvadrat koeficienta asimimetrije (CV^2_a) in srednja vrednost lastnosti (X_{r+l}) glede na velikostni razred (v mm) pri vrstah** S. sindensis **in** S. sihama**.

Character	CV^2_a	X_{r+l}	N	% of individuals with asymmetry
Sardinella sindensis				
Otolith length				
9.0-9.9	42.7	1.99	20	20
10.0-10.9	0	2.05	70	0
11.0-11.9	0	2.40	10	0
12.0-12.9	0	2.55	20	0
13.0-13.9	53.2	2.53	5	20
14.0-14.9	56.2	2.55	5	20
Otolith width				
9.0-9.9	3.60	0.93	20	10
10.0-10.9	14.5	0.95	70	0
11.0-11.9	35.7	1.0	10	0
12.0-12.9	46.8	1.1	20	50
13.0-13.9	57.9	1.0	5	30
14.0-14.9	68.3	1.2	5	20
Otolith thickness				
9.0-9.9	0	0.27	20	0
10.0-10.9	0	0.29	70	0
11.0-11.9	0	0.30	10	0
12.0-12.9	0	0.40	20	0
13.0-13.9	0	0.28	5	0
14.0-14.9	0	0.27	5	0
Sillago sihama				
Otolith length				
15.0-16.9	5.88	6.63	30	83.3
17.0-18.9	2.33	7.32	10	44.4
19.0-20.9	1.70	8.20	20	50
21.0-22.9	5.65	8.93	20	100
23.0-24.9	4.48	10.03	20	100
25.0-26.9	4.65	10.0	20	100
Otolith width				
15.0-16.9	6.47	3.51	30	66.7
17.0-18.9	17.78	3.75	10	33.3
19.0-20.9	19.78	4.13	20	87.5
21.0-22.9	22.35	4.18	20	100
23.0-24.9	29.4	4.85	20	100
25.0-26.9	34.7	4.87	20	100
Otolith thickness				
15.0-16.9	19.02	1.45	30	33.3
17.0-18.9	10.04	1.58	10	22.22
19.0-20.9	17.44	1.94	20	50
21.0-22.9	8.86	2.38	20	50
23.0-24.9	0	2.50	20	0
25.0-26.9	0	2.53	20	0

& Hindberg, 1985), and it is highly possible that these factors may be in action in the Sea of Oman as they seem to be common in the aquatic environment.

Several authors have shown a relationship between the coefficient of asymmetry and fish length (Al-Hassan *et al.,* 1990; Al-Hassan & Hassan, 1994; Al-Hassan & Shwafi, 1997; Jawad, 2001) where there was a trend of an increase in the asymmetry value with the increase in fish length. The otolith morphological characters studied were identical and showed an absence of asymmetry coefficient in several of the size classes studied. The results also show a trend of an increase in otolith width asymmetry value with fish length in the two species studied.

FLUKTUACIJSKA ASIMETRIJA V DOLŽINI, ŠIRINI IN DEBELINI OTOLITA PRI DVEH PELAGIČNIH RIBJIH VRSTAH, ULOVLJENIH V PERZIJSKEM ZALIVU BLIZU BANDAR ABBASA

Laith JAWAD
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth,
PO Box 427, Post Code 100, Muscat, Sultanate of Oman
E-mail: laith_jawad@hotmail.com

Zahra SADIGHZADEH
Department of Marine Biology, Graduate School of Marine Science and Technology, Science and Research Branch,
Islamic Azad University, Tehran, Iran

Dawood AL-MAMARY
Marine Science and Fisheries Centre, Ministry of Agriculture and Fisheries Wealth,
PO Box 427, Post Code 100, Muscat, Sultanate of Oman

POVZETEK

V članku smo izračunali asimetrijo za dolžino, širino in debelino otolita pri dveh pelaških ribjih vrstah, in sicer vrsti Sardinella sindensis *(Clupeidae) in vrsti* Sillago sihama *(Sillaginidae). Rezultati so pokazali, da se pri otolitu* S. sindensis *asimetrija pojavi pri dveh parametrih, pri čemer je največja asimetrija značilna za širino otolita. Pri* S. sihama *je bila med tremi meritvami otolita najvišja vrednost asimetrije izmerjena pri debelini otolita. Pri* S. sindensis *je vrednost asimetrije v debelini otolita enaka nič. Pri* S. sindensis *so bile v okviru treh merjenj otolita najnižje in najvišje vrednosti asimetrije izmerjene pri naslednjih velikostnih razredih: dolžina otolita 9,0-9,9 mm oz. 14,0-14,9 mm; širina otolita 9,0-9,9 mm oz. 14,0-14,9 mm. Pri* S. sihama *se najnižje in najvišje vrednosti asimetrije pojavijo pri naslednjih velikostnih razredih: dolžina otolita 19,0-20,9 mm oz. 21,0-22,9 mm; širina otolita 15,0-16,9 mm oz. 25,0-26,9 mm; debelina otolita 17,0-18,9 mm oz. 19,0-20,9 mm. Možne vzroke za pojavljanje asimetrije pri omenjenih ribjih vrstah smo obravnavali v povezavi z različnimi onesnaževalci, prisotnimi na obravnavanem geografskem področju. Pri obeh ribjih vrstah smo pri širini otolita opazili trend povečevanja asimetrije glede na dolžino ribe.*

Ključne besede: asimetrija, otolit, *Sardinella, Sillago*, Perzijski zaliv, Iran

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